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# ALLIS-CHALMERS Electrical REVIEW


# Power for Progress

This year is Light's Diamond Jubilee, marking the 75th anniversary of the invention of the incandescent lamp by Thomas A. Edison.

When Edison developed the incandescent lamp in 1879, Allis-Chalmers was already an established builder of power equipment. And in the early days of commercial electricity, many A-C steam engines drove dynamos to light arc lamps and Edison's new incandescent lights.

Through the intervening years, A-C has continued to grow with the electric industry, pioneering in all phases of power engineering from generation and distribution through utilization.

Now that the electric industry is celebrating Light's Diamond Jubilee, Allis-Chalmers salutes the achievements of the power companies that have produced the modern era of electricity.

# ALLIS-CHALMERS Electrical REVIEW

## THE COVER

**ACOUSTICAL CONTOURS** help power company engineers determine the noise level of planned transformer installations. In making this contour survey, actual conditions are simulated by superimposing the pattern of background noise recorded at a proposed transformer site in an eastern city on the sound level of the transformer, previously recorded. Speakers and their mounting towers are of special design to duplicate a large area noise source. This low noise level outdoor location at Carrollville, Wisconsin, permits plotting acoustical contours for all desired distances from the noise source under near actual conditions. All equipment is portable, also enabling utility engineers to simulate actual installed conditions by superimposing recorded transformer sound level on ambient noise at any specific proposed installation site.

*A-C Staff Photo by Harold Shrode*


Allis-Chalmers

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## CONTENTS




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Photo courtesy *LOOK* magazine

BUILT IN 1798 near Knoxville in the Clinch River Valley, this mill was in use for 137 years.

# WATER OVER THE DAM

## PART I

by **EDWARD UEHLING**
Hydraulics Section
Allis Chalmers Mfg. Co.

IN THESE TIMES of abundant electric light and power our dependence upon electricity has become so complete that a way of life without it is hard to conceive . . . even though the electric light was invented by Edison only 75 years ago, and electric power generation, in the modern sense, had its beginning only 50 years ago. During the three hundred years preceding our present century, the vast bulk of our power was solely mechanical—first hydraulic, much later both hydraulic and steam.

Recognized as the first application of water power on the North American continent is the grist mill built by early French settlers who located at Port Royal, Nova Scotia. This settlement, established in 1605, is the oldest in North America except for St. Augustine.

At Port Royal, grain was first laboriously ground by hand. Then, according to Marc Lescarbot's record,[1] in 1607 "when the cold weather was over, towards the end of March," Monsieur de Poutrincourt directed who should till the soil, who should put up several additional buildings and, "considering how much toil the hand mill gave us, he ordered a water mill to be made, much to the admiration of the savages." With more leisure "the diligence of our millers furnished us with three times as many herring as were needed to sustain life, for the sea at high tide came up to the mill." In preparing for a long voyage "our water mill came in extremely useful, for otherwise there would have been no way of preparing sufficient flour." Champlain, in his writings, also refers to this first mill . . . "near a waterfall formed by a small river . . . not navigable on account of the number of rocks," on what is now known as Allen's Creek.

**EDITOR'S NOTE: The role Yankee ingenuity played in early water wheel design is a fascinating part of American history. Now, with the Saugus restoration of the first iron works and the fiftieth anniversary of the first Allis-Chalmers hydraulic turbine generator focusing attention on early water wheels, this story is especially appropriate.**

### Overshot wheels power first iron works

The Saugus restoration of America's first successful iron works, now being completed, has created new interest in early American water wheels. In 1641-42, John Winthrop, Jr., son of the original governor of Massachusetts colony, convinced a group of adventurous English investors to establish an iron works on the west bank of the Saugus River, some ten miles northwest of Boston.

Winthrop recruited a group of skilled artisans from English iron mills, one of whom was Joseph Jenks, a well-known mechanical genius and inventor. When the plant was completed, more than 100 men were required to produce about one ton of iron a day from the abundant supply of bog ore and timber for charcoal found in the surrounding countryside. A navigable stream, dammed above the works, provided the necessary water power. It is believed that no less than ten adjacent water wheels were used to power the forging, rolling, and other iron and steel-making machinery.

Painstaking research, excavation, and reconstruction by archeologists, geologists, historians, metallurgists, and architects during the past ten years have brought about a restoration with remarkable fidelity. This work, conducted under the auspices of the First Iron Works Association, Inc., of Saugus, Massachusetts, included the patient digging by an archeological crew which uncovered relics and the water courses that served the iron works during its successful operation from about 1643 to 1675.

Near the blast furnace ruins, about 23 feet below street level, was found a 40 percent section of the original

FIRST SUCCESSFUL iron works was powered by water wheels — the artist's sketch is of one that operated blast furnace bellows. (FIG. 1)

USED TO MILL FLOUR for Washington's troops at the siege of Yorktown, this old tidal mill was still standing in the 1930's near Mathews, Virginia, overlooking Mobjack Bay. (FIGURE 2)

water wheel that powered the blast furnace bellows. It is believed to be the oldest water wheel remnant in this country. Three of the original six spokes and many buckets were found, revealing it to be an overshot wheel about 16 feet in diameter. The fifty buckets were arranged about a foot apart at 50-degree angles. Cams on extensions of the large oak shaft tripped the bellows as the wheel revolved at about 8 rpm, see Figure 1.

## Water grinds colonial corn

Wherever the colonial settlers took root, the construction of waterpowered grist mills was one of their first undertakings. When Captain Newport arrived at Jamestown, Virginia, in 1608 with about 70 persons to supplement the 130 already there, the newcomers were "chiefly artificers" recruited from several countries "to make pitch, tar, potash, glass, etc., and to build mills, and other machines. . . ." Later, in 1621-22, Sir George Yeardley was governor, and his treasurer, George Sandys, as Sir William Keith relates, "ys about the erectinge of a water mill. . . . "[2]

Near Smithfield, Virginia, Wrenn's old grist mill, built in 1642 by George Hardy, was still operating in 1907.[3] The wheel was replaced by a water turbine about 1930.[4]

In New England, the "water mill" at Dorchester, Massachusetts, built by Israel Stoughton about 1633, is claimed to be the first one.[5] At the site of Watertown, another "water mill" was "half owned by Matthew Craddock," the other half interest is recorded as having been sold in 1635 for 200 pounds. Although "Indians pounded corn" for the colonists, why twelve years elapsed between the landing of the Pilgrims in 1620 and the building of their first mills is hard to understand, unless possibly it was a shortage of millstones, which had to be imported from England. The lower falls of the Neponset River at Dorchester, where the head was eight feet, has been in use for more than 300 years — successively as a grist mill, saw mill, powder mill, and much later as a chocolate factory.

Farther north, Ipswich, Massachusetts, in 1635 granted R. Saltonstall permission to build a grist mill—the toll to the customer being one-sixteenth of the grain ground. Salem had a "water mill" for grinding corn in 1636. One was built by Richard Dummer at Newbury in 1638, another in 1639 by a Mr. Buckeley at Concord. Duxbury made "an allowance" for building a "water mill" in 1638. The overshot wheel of the Old Town Mill in New London, Connecticut, dates back to about 1650.

Grist mills began with new settlements and the use of water power increased at older sites. In addition to grist mills, there was the sawing of lumber, "breaking" of hemp, carding of wool, some fulling of cloth, and other industrial uses, such as at Saugus.

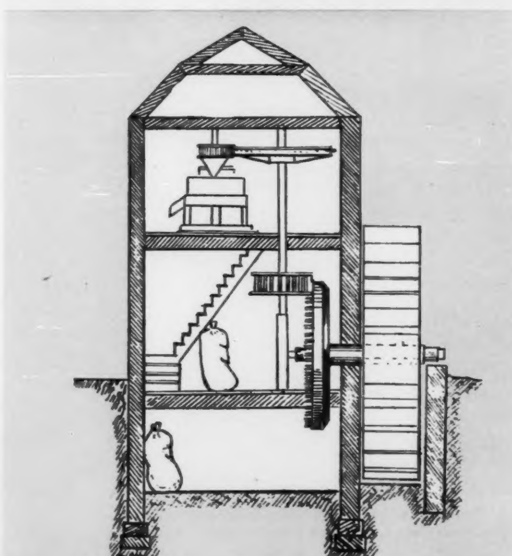
An interesting example of early cooperative effort in developing a much needed water power site is said to have occurred at Stamford, Connecticut, around the middle 1600's. To get a grist mill located here, the town built a dam. Then a Samuel Swane, aided by craftsmen, built the mill itself, which was later sold to other interests.

Pawtucket (Fall of the Waters), Rhode Island, was settled about 1670 by Joseph Jenks, Jr., and because he was an iron worker like his father at Saugus, this location on the west bank of the Blackstone River became a center of skilled iron workers. Pawtucket, more than a century later, was the first community to utilize water power for textile manufacture—an industry which prospered because of abundant water power in the eastern states. The 1810 census lists 109 New England cotton mills, three-quarters of them in the Pawtucket and Blackstone river valleys.

## Ocean tides put to work

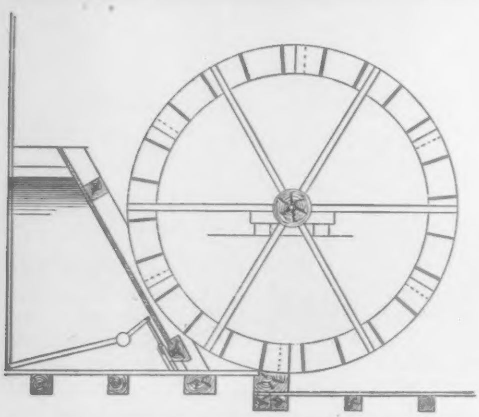
Scattered tidal mills in protected locations along the coastal areas were a part of the early water power develop-

TYPICAL of its time is this corn mill of the 1730's. (FIGURE 3)

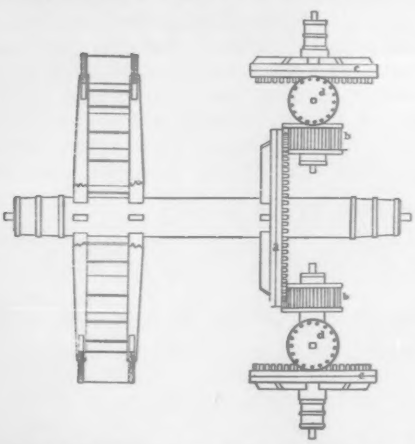


ments. In addition to the "water mill" at Salem in 1636, mention is made of a Captain Trask's "tide mill"[5] in 1638. An historical account of the Town of Hingham, Massachusetts, states: "In 1643, June 12, Anthony Eames, Samuel Ward, and Bozoan Allen had leave from the town to set up a corn mill near the cove, on condition that they paid any damage caused by flowage, etc."[6]

An early account of "Boston and the Colony" mentions that tide mills "were also introduced.... For the purpose of encouraging the erection of a water mill, the town granted, in July 1643, all the cove and salt marsh bordering upon it northwest of the causeway leading to Charlestown, together with three hundred acres of land at Baintree, on condition that the grantees should, within three years, erect one or more corn mills to be maintained forever." Furthermore, "in order that the grant to mill owners might not interfere with the rights of other persons, the grantees were required to make and maintain forever a gate ten feet in width, to open at flood tide for the passage of boats."[7] Mills like the one near Mathews, Virginia, see Figure 2, turned in one direction when the tide came in, and in the other as the tide moved out.



**EARLY UNDERSHOT** wheels, in many cases, merely had radial bucket divisions or floats. **(FIGURE 4)**



**GEAR TRAINS** between water wheels and mill stones were wooden, as were the wheels. **(FIGURE 5)**

## The age of wooden wheels

Water wheels of our first two centuries, and even later, were almost completely wooden creations. Lumber from virgin forests then was plentiful. Iron was still scarce, and was channeled into more important uses.

We are indebted to a civil engineer, named Joseph P. Frizell, who more than 60 years ago illustrated and described "The Old Time Water Wheels of America"[8] as used in the 18th century. His information was drawn from much older sources, including an old book of Oliver Evans,[9] and from old lawsuits about water grants. From his writings we learn that the early types of water wheels were usually overshot, undershot, or breast wheels and, according to the application, differed only in the method of letting the water onto the wheel. Most of the wheels were designed by the millwrights who built them — practical men who had learned their trade well.

These early wooden water wheels consisted of five principal parts: the shaft, arms, shrouding, soling or inner circumferences of the shrouding, and the floats or partitions which formed the buckets. The shafts were oak logs 18 to 30 inches in diameter, dressed square, polygonal, or circular, with iron bands around them. All wheels ran on iron gudgeons inserted into the shaft ends. Oliver Evans pointed out that the gudgeons ran on stone bearings.

### *Undershot wheels commonly used*

Undershot water wheels were in common use for driving grist mills. Figure 4 shows an early wheel with six arms and radial floats. Figure 5 shows the style of gearing, with all-wood teeth, used in one-run and two-run millstones. They were never geared to more than two. In Figure 5, *a* was known as "the big face wheel," with gears driving one or two "wallowers" *bb*. "Little face wheels" *c* on the wallower shafts in turn were geared to "trundles" *d*. These were attached to the millstone spindles — the gear train being designed for a peripheral speed of about 1500 feet per minute. The wallower gudgeon nearest the main shaft

**EARLY SAW MILLS** were usually driven by faster, small diameter flutter wheels. **(FIG. 6)**

**OHIO'S FIRST GRIST** and saw mill, built in 1789, was on Wolf's Creek near Marietta. **(FIGURE 7)**

From *The American Pioneer*, 18

rested in a sliding block which permitted either wallower to be disengaged. These or closely analogous drives were considered "tops" for centuries.

Flutter wheels, essentially undershot-paddle wheels minus any sole ring of shrouding, were often exceedingly crude. Their principal application was powering saw mills, and they were of small diameter to give the usual 120 strokes per minute under ordinary low heads. The floats were wide in proportion to diameter. One end of the shaft was provided with a crank, as shown in Figure 6.

The paddle wheel itself, except for diameter and speed, was not markedly different from the tidal mill wheel illustrated in Figure 2. At a much later date this general wheel construction was also used in fast-moving streams for developing small amounts of power, Figure 7.

*Breast wheel but another form*

The "Economic and Social History of New England"[5] states that in 1655 John Pierpont and others had "sett down a brest mill or undershott where the old mill stood" in Roxbury.

These wheels were built to meet individual requirements. They were often of large diameter. For low heads the water was let on to the wheel at some point half way or lower (if let on near the bottom it became undershot). For higher heads the water was let on at some point below the sole ring of the floats. Figure 8 illustrates a high breast wheel of early construction with floats tilted.

## Water powers early industrial growth

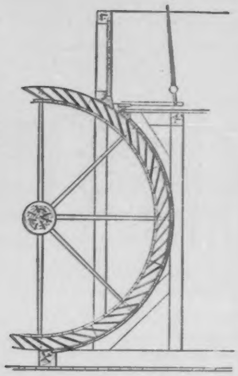
After the Revolutionary War an earnest desire to become self-sustaining in our manufacturing enterprises led to more extensive water power development wherever feasible. An almost unbelievable number of new towns sprang up in locations where water power was available. Our economy, with its rising standard of living, would have suffered greatly without this boon of water power.

By 1790 a spinning mill had been built at Pawtucket, Rhode Island, because of abundantly available water power. Here Samuel Slater reproduced from memory the first Arkwright machine in this country for making cotton goods. The many spinning and weaving machines that gradually came into existence here gave New England its start in the great textile industry. It was 1830 before the first steam-driven mill was erected at Providence.

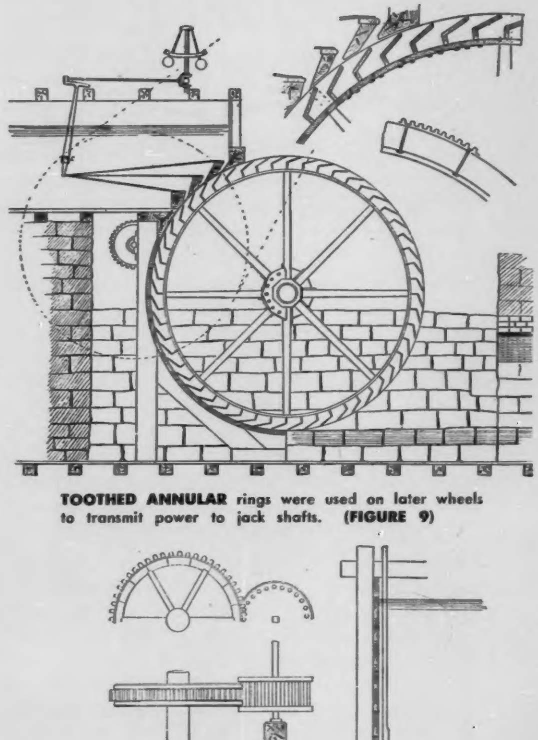
Another early large water power development took place at Paterson, New Jersey. Here on November 22, 1791, was incorporated the Society for Establishing Useful Manufactures. The nearby Great Falls of the Passaic River was selected as a favorable site for its enterprise, and the town was established in 1792. Cotton manufacture was the first industry established after the dam was built in 1794. By 1800 some Paterson mills were making machinery, and by 1839 the silk industry was started there.

The fast growth and expansion of industry in the early 1800's called for power in increasing quantities. Scores of towns thrived because easily developed water power sites were available. Within a few years after the War of 1812, 34 companies were established in Massachusetts alone for manufacture of woolen and cotton cloth, bringing into existence Lowell and Lawrence in Massachusetts and many

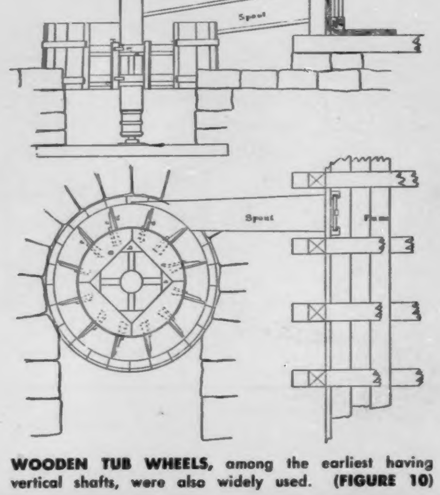




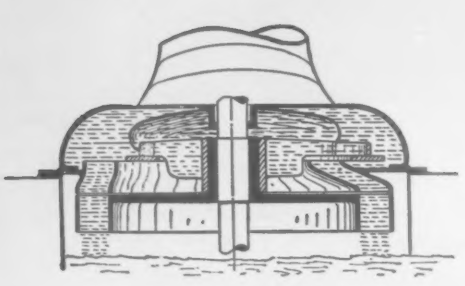
**TILTED FLOATS** and aprons made early high breast wheels like this one more effective. **(FIGURE 8)**



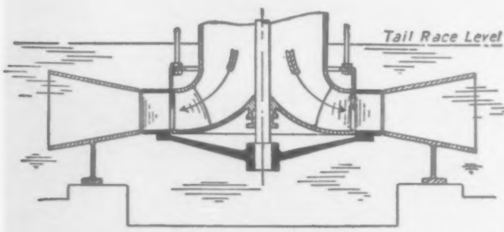
**TOOTHED ANNULAR** rings were used on later wheels to transmit power to jack shafts. **(FIGURE 9)**



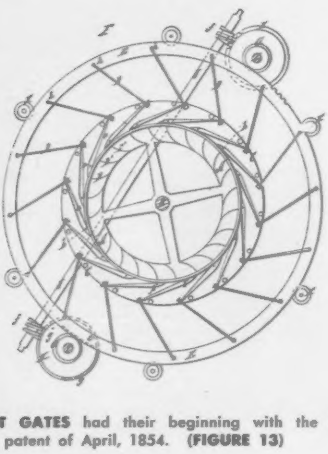

**WOODEN TUB WHEELS,** among the earliest having vertical shafts, were also widely used. **(FIGURE 10)**



**AXIAL FLOW** Jonval turbines had runner buckets on the outer periphery of the runner. **(FIGURE 11)**




**THIS OUTWARD FLOW** Fourneyron turbine is shown equipped with a Boyden diffuser. **(FIGURE 12)**



**WICKET GATES** had their beginning with the Elijah Roberts patent of April, 1854. **(FIGURE 13)**

towns in New England and elsewhere. Rivers were largely developed in easy stages of 10 to 20 feet, with several levels of canals where necessary to accomplish this end. Individual water wheels were all of small horsepower.

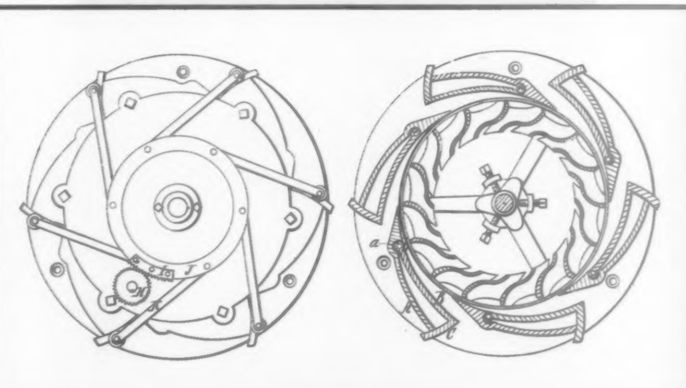
The rivers of New England were largely developed as a joint effort of many manufacturing companies of all types participating in a major development. A development company like the Proprietors of the Locks and Canals at Lowell looked after the canals, headworks and flumes, and distributed water to their manufacturing clients for annual rentals and other fees. Because of standards set up at Lowell and later at Holyoke, their outstanding contributions cannot be ignored.

With railroads still in the future, large rivers like the Merrimack became important arteries of commerce. Chief hindrance on the Merrimack was the 32-foot drop of the Pawtucket Falls, future site of the great industrial city of Lowell, Massachusetts. In 1792 the Locks and Canals Company on the Merrimack was formed to make the stream navigable all the way into New Hampshire — providing mutually profitable water transportation between Concord and Boston. By 1801 the Middlesex Canal around Pawtucket Falls was completed.

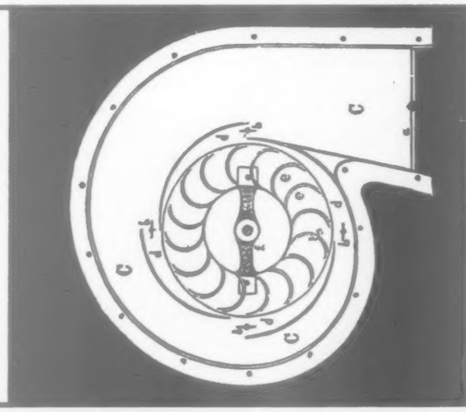
When the Merrimack Manufacturing Company decided to use power at this location for making cloth, the Pawtucket Canal was greatly enlarged, a dam constructed, and a lateral canal built to the mill. From this beginning in 1821, the commercial development of some 25,000 hp available at Pawtucket Falls increased by leaps and bounds. By 1826 the Proprietors had established a machine shop for the construction of general machinery. To this, in 1834, was added the building of our country's early locomotives. Eventually, factories using water power from the canals of Lowell stretched for miles along the river front.

As larger river developments for textile, paper, and other mills took place, advanced varieties of breast wheels seemed to predominate. They were much bigger than the old grist mill wheels, often 20 or more feet long axially, with diameters dependent upon the fall.

Some typical mechanical improvements of that time are indicated by the wheel shown in Figure 9, built for a 20-foot head. It had four sets of arms and shrouding, with the end shroudings being heaviest. The buckets had two parts — the "start" being radial to the wheel, and the float usually tangential to the soling. Used with an apron ex-



**THE JOHN TEMPLE** patent of February, 1857, had another form of pivoted gates. **(FIGURE 14)**



**SPIRAL GUIDES** with damper-type gates were used on this improved Goodwin turbine. **(FIGURE 15)**

tending to the bottom, the wheel gave better efficiencies. A series of segments bolted on the heavy end shrouding formed a toothed annular ring through which power was transmitted to a pinion or jack gear, as shown. Some attempt at speed regulation is also indicated. Improvements continued and, before long, iron shafts were used. By 1844 the Prescott Mills at Lowell had several 16-foot diameter wheels constructed almost entirely of cast iron.

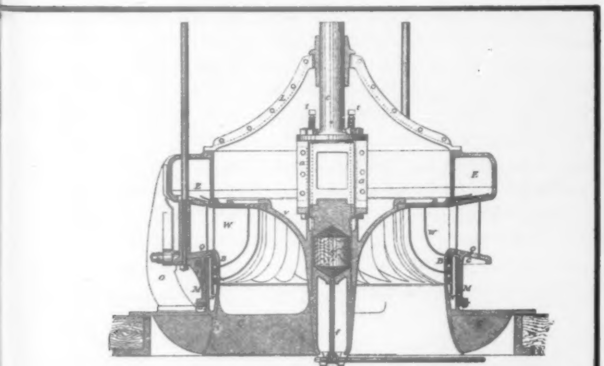
## Tub wheel extensively used

Another form of wheel extensively used for grist mill applications was known as the tub mill, Figure 10. With a vertical instead of horizontal shaft, the wheel ran in a circular wood enclosure, or tub without a bottom. In one sense it was merely a kind of vertical flutter wheel. The water was let on at an angle through a crude spout, and the tub, a continuous apron, confined the water to the wheel on its downward course. In somewhat improved later designs, the floats or paddles were often set at an inclined position to be more nearly perpendicular to the angle of the water impinging on them. A wheel of this construction was still in operation in the early 1860's at the machine shop in Lowell. Isolated wheels of this type were found in old mills to the end of the 19th century.

In some cases ingenious craftsmen attached the rim portion right to the outer diameter of the floats, so that the tub revolved as an integral part of the wheel. With just a little imagination one can see an embryo turbine runner of a century later.

## Francis starts Lowell career

Each water power development, like the one along the Merrimack, needed a super master mechanic and engineer to look after the projects. In 1837, when his boss left, a promising young man named James B. Francis[10] became the "engineer of Locks and Canals Company" for the Proprietors at Lowell. In this capacity, he was recognized as the consulting engineer to the wide variety of manufacturing enterprises deriving power from the Merrimack River at Lowell. One of his duties was allotting water power to the several companies and determining its value in accordance with their privileges. His famous "Lowell Experiments" grew out of the necessity for a practical determination of the amount of water distributed to the various mills for their daily operation under all contingencies of flow. As early as 1846 he constructed the Northern Canal to increase available water power at Lowell, and reconstructed the Pawtucket Dam — no mean undertaking. The work James Francis carried out during his fifty years with the Locks and Canals Company was monumental — undoubtedly making him the greatest hydraulic engineer of all time.



**THIS SWAIN TURBINE,** rated 330 hp, was tested by James Francis for Boott Cotton Mills in 1874. **(FIG. 16)**

## Nineteenth century brings the turbine

The traditional types of water wheels persisted well into the 19th century, with metal construction frequently replacing wood. However, the possibilities of the turbine type were soon apparent. Their smaller size, ease of construction in metal, greater speed and freedom from ice troubles, gave them quick acceptance wherever old power sites were expanded or improved, or new sites developed.

One of the earliest iron turbines is said to have been a wrought iron tub wheel installed in 1817 in a paper mill at the lower falls of the Neponset River at Milton, Massachusetts.[11] Other early crude designs were attempted.

Concurrent with American developments, two basic reaction-type wheels came into existence in Europe. With experiments begun in 1823 in France, Fourneyron by 1827 developed his outward-flow type turbine. In 1837 Henschel in Germany and 1839 Fontaine in France developed axial-flow turbines with runner vanes or buckets located at the outer peripheries of the wheels. These were improved by Jonval in 1841 and became known as the Jonval type, Figure 11. Both types were used in Europe for decades.

In 1838 Samuel Howd, of Geneva, New York, patented an inward-flow turbine runner. Its flow was opposite to that of the Fourneyron runner and its principle later became basic to American turbine design. He also patented an outward-flow turbine for which he licensed builders. James Francis recognized the superior characteristics of the Howd inward-flow wheel and, as agent for the Proprietors of Locks and Canals, secured the rights for this Howd wheel for the locality around Lowell. In 1849 he developed an improved Howd design for use at the Boott Mills, which gave nearly 80 percent efficiency.

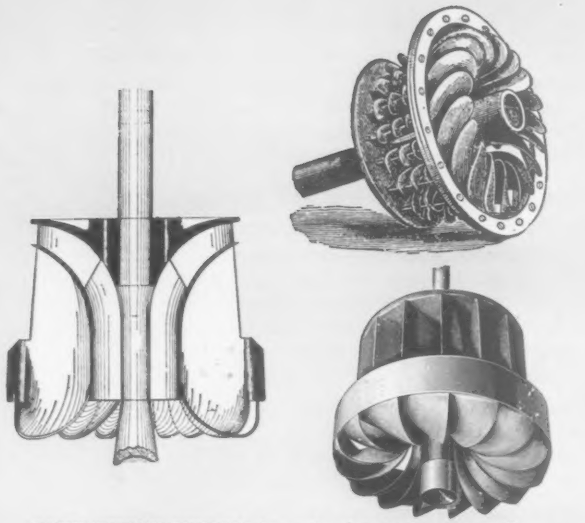
Uriah A. Boyden, inventor of the hook gauge, designed a successful, well-thought-out turbine in 1844 for the Appleton Mills at Lowell. This incorporated the outward-flow Fourneyron type. It was a great improvement, however, both hydraulically and mechanically, and included a diffuser around the runner discharge, see Figure 12. He was the first to appreciate that some energy remained in the water at the time it discharged from the turbine runner. To recapture part of this, he invented the Boyden diffuser, which improved efficiency about 3 percent.

Both Boyden and Francis used scientific approaches in designing their wheels and constructed their turbines only after making full-scale drawings. While Boyden's runner was the outward Fourneyron type and the Howd-Francis was still only a straight inward-flow turbine, these two American designs were long strides forward.

## Mixed flow evolves

Clemens Herschel* once said that between the 1840's and 1900 more than 60 varieties of cheap cast-iron American turbines, built under innumerable U.S. Patents, were developed. By the 1860's every isolated local machine shop

* First manager (1904) Allis-Chalmers Hydraulics Dept., inventor of Venturi meter.



**EARLY TURBINE RUNNERS** known by their trade names and among the most widely used by the end of the 19th century were *Samson* (left), *Hercules* (upper), and *American*. (FIG. 17)

was building small water wheels to meet the increasing demand. By sheer "cut and try" methods, without reference to any Boydens or Francises, many were building turbines according to their own pet ideas, some fantastic.

As Safford and Hamilton pointed out in their excellent treatise on "The American Mixed-Flow Turbine and Its Setting," the end result evolved was the American mixed-flow turbine which eventually combined, in the right proportion, the inward-flow principle of the Howd-Francis wheel and the downward flow of the tub and Jonval wheels: "This was a real American production, the result of evolution during a changing American history. The need arose, made itself felt, and eventually was met, not by the work of one great scientist, but by the multitudinous efforts of an army of old Yankee millwrights and machinists, many of . . . whom are . . . forgotten."

By 1849 another great river, with a potential of some 50,000 horsepower, was started into service. The proprietor was the Holyoke Water Power Company, which controlled the flow of the Connecticut River at Holyoke, Massachusetts. To utilize the fall of 60 feet in convenient steps, they too constructed a dam and a series of canals which, like those at Lowell, brought the water to other power-hungry mills. Around 160 water wheels were operating in the Holyoke area as the 19th century ended.

In 1869, toward the end of the "cut and try" period, an odd but outstanding character named James Emerson became interested in testing water wheels. Many years later Herschel referred to him as "a retired 'sea-captain,' one of these downeast Yankees produced habitually in that section of the U.S." who "took it into his head that unsupported talk and brag by wheel builders had gone on long enough and began to test turbines for efficiency," first at Lowell and then at Holyoke. His business forged ahead and his reports kept the public informed. The builders of good and better wheels had nothing to fear, and poorer wheels were gradually eliminated.

In 1879, Clemens Herschel was appointed hydraulic engineer for the Holyoke Water Power Company — with responsibilities similar to those of Francis at Lowell, with whom he had worked occasionally. Emerson's testing flume was taken over by the proprietors at Holyoke, and in 1881 the now famous Holyoke testing flume was built under Herschel's direction. Turbine builders began to see the wisdom of testing moderate-sized models of their own wheels, and later learned to predict results of large installations. Between 1882 and 1932 over 3000 such commercial tests were made. The Holyoke testing flume was shut down in 1937, as all major turbine companies had long since built more adequate testing flumes of their own.

## Other developments improve turbine

Besides the several inventions already touched on, a few more should be included. In June 1840, Zebulon and Austin Parker, of Licking County, Ohio, were granted a patent for a "Draft Tube for Water Wheels." Not until many years later was the draft tube considered as a means of gaining efficiency. It was merely a device by which the wheel could be raised clear and above tailwater and still retain full head, with the added advantage of making the turbine more easily accessible for inspections and repairs. As pointed out, only Uriah Boyden seems to have sensed the possibility of regain by using the diffuser.

Many ingenious schemes were worked out for some control of water flowing into the turbine. A commonly used device was the cylinder gate, which is still used on some makes of small turbines even today. It was simply a cylinder raised or lowered by a rack and pinion, and it usually moved in an annular space between the fixed guides and the runner, but sometimes on the outside of the stationary guides. Another device used was a register gate, in which an outer ring with alternate openings was rotated enough to partially or wholly shut off the openings between the fixed guides.

### *Multiple gates appear*

All sorts of adjustable gate mechanisms were devised. Three early patents of the 1850's are here illustrated, two having had especially wide and successful usage. One, Figure 13, covered the original adjustable wicket gates, patented in April 1854 by Elijah Roberts, of Rochester, New Hampshire. This was the beginning of pivoted wicket gates operated from an outer shifting ring. Another pivoted gate accomplishing more or less the same thing in a little different form, Figure 14, was patented by John Temple, of Middletown, Ohio, in February 1857. In his device, pivoted gates worked between stationary guides and were operated from an inner shifting ring.

An entirely different type of gate design is shown in Figure 15 in a greatly improved Goodwin turbine.† While the original patent of Lorenzo D. Goodwin, of Peruville, New York, merely covered an inward-flow runner with a wooden spiral casing, the later design shows that stationary spiral guides were introduced with small rectangular pivoted shutoff gates between them. These were operated by a small inner shifting ring on top of the metal cover. In addition, there was a main rectangular pivoted shutoff valve at the entrance to the casing. These turbines were used to drive grist and saw mills under low heads.

† Built by E. P. Allis Co. (later Allis-Chalmers Mfg. Co.) in the 1860's.

Safford mentions that after 1850 many wheels with scrolls came into use but disappeared with the coming of the cheap boilermaker-type turbines. Cast-iron scroll cases came into use in Europe, and later here, when higher head turbines were attempted during the latter part of the 19th century, and for lower heads when reinforced concrete made modern settings possible.

Among the heroic early attempts at building turbines, other things being equal, those which combined the inward and downward principles of our modern mixed-flow turbines were the ones which had greatest acceptance.

## Swain turbines prove worth

Asa M. Swain in 1858 made a model runner much like the Howd-Francis, with a greater number of deeper buckets curved outward from the inner discharge edge, but providing a mixed flow that was inward and downward. Safford called it "the direct predecessor of the modern low-speed reaction wheel." By about 1871 a number of Swain turbines were installed at Lowell to replace outward-flow Boydens and breast wheels.

In 1874 James Francis made a comprehensive test for the Boott Cotton Mills of Lowell on a 72-inch diameter Swain turbine of about 330-hp capacity under 18-foot head. The cross section of this unit, shown in Figure 16, is from Francis' test report published in 1875. It had a rather cumbersome cylinder gate type control with "fixed" guides which lifted up into the cover, permitting a trailing cylinder to follow in its place. The oak water-lubricated step-type thrust bearing was supported by "the lower curb ring *C*," which had a short upward cylindrical extension that guided the cylinder gate. Although it had no draft tube, it showed 84 percent efficiency.

Some have maintained that our modern wheels should be called Swain runners, or just mixed-flow runners, rather than Francis runners. Safford points out, however, that Swain, a patternmaker, arrived at his design by "cut and try" methods and that his runner was really a direct development of the early Howd-Francis. Few will begrudge the tribute paid to James Francis in naming our modern runners after him.

## Other good makes succeed

By 1870 an inward and downward mixed-flow turbine with the trade name of *American* water wheel, Figure 17, had gained wide distribution, especially for small grist mills and saw mills. Stout, Mills and Temple, organized in 1853 (later the Globe Iron Works), built these successful turbines in stock sizes. Their adjustable guides, covered by the Temple patent of 1859, were given wide promotion in their catalogs. This firm also built cylinder-type gates for "those who may be prejudiced in favor of cylinder gates with stationary guides." A catalog of about 1900 refers to their improved line of *New American* turbines and includes two 1898 Holyoke test reports. One 36-inch wheel shows a best-point of 86.76 percent.

Double runners as built by Leffel as early as 1862 obtained a far wider distribution. These runners combined, in one wheel, an upper separate part for inward flow, with a larger lower part that was both inward and downward. These turbines, it is said, were equipped with wicket-type gates. A 1900 catalog states that over 15,000 of their wheels (presumably all styles and types) were then in use and supplying over one million horsepower. Many units, of course, had two or more pairs of wheels. "*Samson* Wheel Efficiency Tables" in the same catalog show 1897 Holyoke efficiency of 84.78 for a 35-inch wheel, the *Samson* being one of their later double-runner turbines.

The Risdon wheel of 1873 was another successful wheel of the inward and downward-flow type, but buckets did not extend downward and outward below the discharge band. Safford states that "the Risdon Company was the first, since Boyden, to appreciate the diffuser, or draft tube, and to apply it to its wheels. The wheel tested in 1873 gave an efficiency of 90.5 percent with the diffuser, and 88.8 percent without it." Risdon wheels were equipped with cylinder gates.

The first of the famous *Hercules* wheels, built by Holyoke Machine Company, had an inward, downward flow and outward flow below the discharge band. The buckets had several series of fins along the line of flow, dividing the runner into sections. This was supposed to give better part-load efficiencies with the cylinder gates. A 36-inch wheel tested at Holyoke in 1883 showed 87 percent full-load and 73 percent half-load efficiencies.

Still another successful inward and downward-flow runner with buckets projecting below the discharge band was the *Victor* wheel built by Stilwell Bierce. It had register-type gates, and is said to have had less efficiency than the *Hercules*. A pair of *Victor* wheels which were installed by a Wisconsin utility company about 1901 are shown.

In every state of development from a small beginning in Nova Scotia through its evolution into the present century, water power has played an important role in the progress of America.

REFERENCES

1. *History of New France,* Vol. II, Marc Lescarbot, Champlain Society Edition.

2. *History of the British Plantations in America,* Part I, Sir William Keith, London, 1738.

3. *Isle of Wight County (Virginia), 1608-1907,* Colonel E. M. Morrison, for Jamestown Tercentenary Exposition.

4. From June, 1954, letter by S. C. Dashiell, Pres. Smithfield (Va.) Library Association.

5. *Economic and Social History of New England,* Volume I, W. B. Wheeden, Houghton Mifflin & Company, Boston, 1894.

6. *History Town of Hingham,* Sol Lincoln, 1827, Farmer and Brown, printers.

7. *Memorial History of Boston,* Vol. I, Justin Winsor, James R. Osgood & Company, Boston, 1880.

8. *Transactions,* American Society of Civil Engineers, Vol. 28, April 1893.

9. *The Young Mill-wright and Miller's Guide,* 1795.

10. "Biographical Sketch," Proceedings of American Society of Civil Engineers, Vol. 19, April 1893.

11. *The American Mixed-Flow Turbine and Its Setting,* A. T. Safford and E. P. Hamilton, ASCE *Transactions,* Vol. 85, April 1922.

**THREE PAIRS** of 42-inch cast-iron *Victor* wheels like these, with shafts coupled end to end, supplied 1600 hp at 15-foot head. **(FIGURE 18)**

# A Simple Method of PARALLELING LOAD TAP-CHANGING TRANSFORMERS

REQUIREMENTS for paralleling these two load tap-changing 13,300-kva transformers may fit this method.

by W. C. SEALEY
Chief Engineer
Transformer Section
Allis-Chalmers Mfg. Co.

*You may be able to eliminate control connections and accessories normally used for paralleling transformers.*

WHEN TRANSFORMERS with automatic load tap changing are operated in parallel, some method of preventing excessive circulating current between units is required. One simple method suitable for many installations requires no control connections between transformers and no additional equipment. Reverse reactance compensation combined with positive resistance compensation is utilized in this method of paralleling load tap-changing transformers. This method is best applied when the following conditions exist simultaneously:

1. When the power factor at full load is high.

2. When any large changes in load power factor are confined to light loads.

3. When the circuit impedance has a high ratio of reactance to resistance.

It can also be used successfully in many instances even though there is considerable deviation from these ideal conditions. A description of characteristics of the method and its limitations is given to aid in applying the method to installations where it is suitable.

Many transformers are equipped with automatic load tap-changing equipment to change their voltage ratios and maintain constant voltage at the transformer terminals or at load centers. This equipment can maintain constant voltage at load centers remote from the transformers by means of line-drop compensation. The operating motor of the load tap-changing equipment is controlled by a voltage regulating relay ($V$) connected to a potential transformer across the secondary winding of the transformer being controlled. The line-drop compensator has a current, proportional to the line current, circulating through a resistance and reactance in series with the voltage regulating relay, as shown in Figure 1. The arrangement provides the same effect as pilot wires run from the load center to the voltage regulating relay, and hence constant voltage is maintained at the load center.

If the circuit of Figure 1 is used for two transformers connected in parallel and on different tap positions, the circulating current between the units will tend to drive the automatic load tap changers to tap positions farther apart, causing the circulating current to increase excessively.

## Reverse reactance compensation used

Various means are used to keep the tap positions sufficiently close together to minimize the circulating current between units. Some of these schemes require control

interconnections between units and auxiliary equipment. Interconnections are particularly undesirable when the units are located at a considerable distance from each other.

One scheme which requires no control interconnections depends on reversing the connections of the reactance element of the line-drop compensator and changing its setting to produce a drooping characteristic of voltage as the load increases. If the power factor of the load is high, this drooping voltage effect can be overcome by increasing the setting of the resistance compensator. The resistance compensation overcomes both the effect of the line drop from the transformer to the load center and the negative reactance element of the line-drop compensator. However, such a combined setting of the reactance and resistance elements is correct for only one particular load power factor. If the power factor of the load changes, the voltage being controlled at the load center will also change.

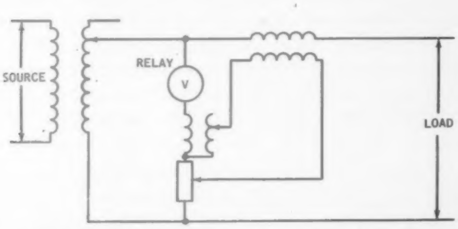
Figure 2 shows the complete circuit used for reverse reactance compensation of transformers. Impedances $Z_1$ and $Z_2$ are in series with the primary and secondary lines, respectively. Impedance $Z_1$, from the point of paralleling to the secondary side of the transformer, includes the transformer impedance, while $Z_2$ is the impedance from the transformer to the load center.

## Circulating current limited

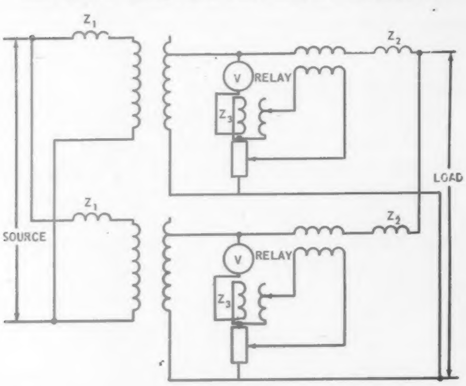
If two load tap-changing transformers are operated in parallel, there must be sufficient impedance in their power circuits to limit the circulating current to safe values, even though the transformers are on slightly different taps. Two-winding power transformers generally have sufficient impedance for this purpose. However, autotransformers, such as feeder voltage regulators, usually do not have sufficient inherent impedance to permit direct connection in parallel without additional impedance in series, either on their primary or secondary sides. This additional impedance may consist of reactors, other transformers or line impedance.

The amount of the circulating current between two transformers connected in parallel when their ratios are slightly different is equal to the difference in the no-load secondary voltages divided by the impedances in the path of the circulating current, which in Figure 2 is $2(Z_1 + Z_2)$. For example, if the sum of $Z_1$ and $Z_2$ is 10 percent and there is 4 percent difference in no-load secondary voltage between the units, the circulating current will be equal to 4 percent divided by 0.20, which equals 20 percent of full-load current. This will be a lagging current for the transformer on the higher voltage tap and a leading current for the transformer on the lower voltage tap. Its effect on the negative reactance compensator could be indicated on a voltmeter connected to the transformer on the higher voltage tap. If this circulating current is at a very low power factor, the indication shows that this transformer's voltage is too high by the product of the circulating current and the amount of the compensation. With a 20 percent circulating current and a setting of the line-drop compensator for a reverse reactance of 5 percent, the voltmeter will indicate that the voltage is 20 times .05, or 1 percent too high. The indication on the other transformer will show that the voltage is 1 percent too low.

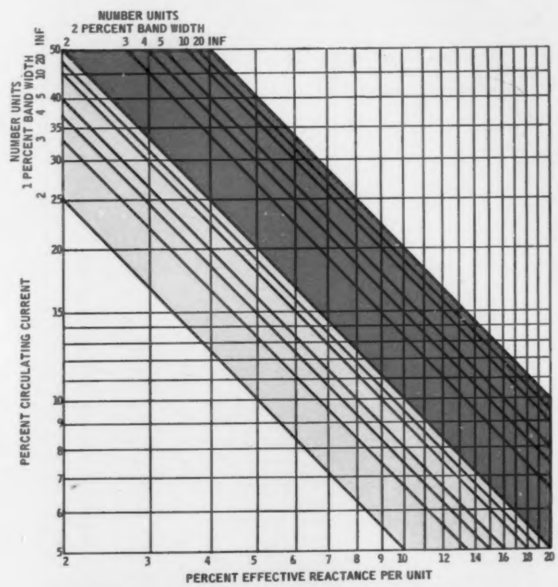
With a circulating current of 20 percent at right angles to the load current, the load will increase 2 percent on each unit. However, with a phase angle of 45 degrees between the load current and the circulating current, a 20 percent circulating current would result in a 15 percent increase



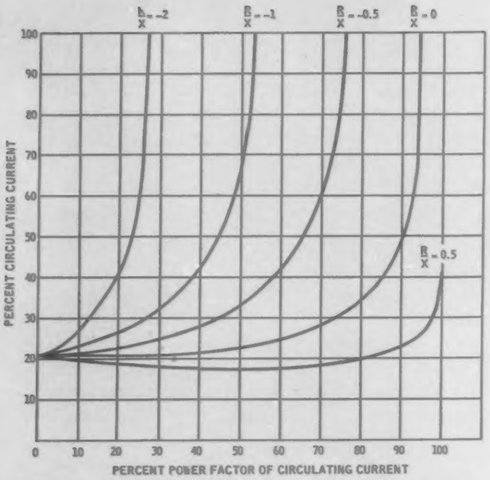

**LINE-DROP COMPENSATOR** is normally used to offset increased line voltage drop with added load. **(FIGURE 1)**




**REVERSE REACTANCE COMPENSATION** resembles line-drop compensation but reactance is reversed. **(FIGURE 2)**



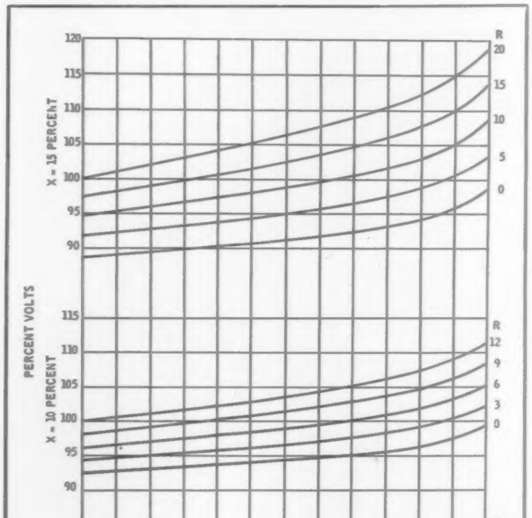

**RELATION** of effective reactance to zero power factor circulating current is shown for 1 and 2 percent band widths. **(FIGURE 3)**




**POWER FACTOR** of circulating current is an important factor in determining percent of circulating current. **(FIGURE 4)**


$E$ = scalar value of voltage to be held.
$V_1$ = voltage at transformer secondary terminals.
$V$ = voltage at load center.
$IX$ = voltage of reactance compensator.
$IR$ = voltage of resistance compensator
$IX_2$ = reactance voltage drop in secondary line.
$IR_2$ = resistance voltage drop in secondary line.

**TRANSFORMER SECONDARY** and load center voltages can be shown by this vectorial relationship. **(FIGURE 5)**




**BASIC CURVES** may be developed from vector relation of load center voltage to load power factor. **(FIGURE 6)**

in load current on one unit and a 13 percent decrease in load on the other.

The amount of zero power factor circulating current between two paralleled transformers permitted by the control is equal to the band width divided by twice the effective reactance. The effective reactance is equal to the sum of the secondary line reactance plus the reversed reactance of the compensator. Both are expressed in the same percentage terms.

From these relations it is evident that the circulating current can be reduced by decreasing the voltage band width or by increasing the effective reactance.

When more than two transformers are operated in parallel, the circulating current of any one can increase over the value for two transformers. The amount of circulating current for a given band width and effective reactance increases with the number of units, as shown in Figure 3. These curves are drawn for zero power factor circulating current.

The equation for any number of identical, paralleled transformers is

$$\text{Maximum circulating current} = (\text{Circulating current for two transformers})\left(2 - \frac{2}{N}\right)$$

where $N$ is the number of units operated in parallel.

Since all actual circuits contain resistance, the power factor of the circulating current may be near but never equal to zero. The curves of Figure 4 are drawn to show the effect of the power factor of the circulating current on its magnitude. These curves are drawn for a large number of units in parallel for a 2 percent voltage control band and a 10 percent reactance. For the same ratio of $R/X$, and circulating current power factor, the magnitude of the circulating current is inversely proportional to the effective reactance and approximately directly proportional to the band width. These curves show how the magnitude of the circulating current increases with its power factor.

In Figure 4 the circulating current is approximately proportional to band width and is inversely proportional to the reactance for same value of $R/X$.

To obtain the approximate value of $R/X$ for any number of units in parallel, multiply the circulating current taken from Figure 4 by a corresponding factor taken from Table I.

## Voltage variation determined

The voltage at the transformer terminals is equal to the vector sum of the voltage maintained at no load plus the compensator resistance drop minus the compensator reactance drop. The voltage at the load center is equal to the vector sum of the voltage at the transformer secondary terminals minus the secondary line reactance drop and minus the secondary line resistance drop.*

These relations are shown by the vector diagram of Figure 5, which indicates that the effect on the load center voltage of the reverse reactance in the compensator is exactly the same as the reactance of the line. The diagram also indicates that the effective resistance drop is equal

* For equations and their derivation, refer to AIEE paper 54-205.

to the difference between the resistance drop in the line and the voltage of the resistance element of the line-drop compensator. This difference between the resistance drop of the line and of the line-drop compensator is called the effective resistance. The effective reactance is equal to the sum of the reactance drop of the line and of the reactance element of the line-drop compensator. The performance curves have been calculated based on the relations shown in the vector diagram.

The curves of Figure 6 represent the values of voltage which will be held at the load center for different values of effective resistance and effective reactance for 70 to 100 percent lagging power factor loads. These are basic full-load curves which represent the voltage at the load center. The voltage variations at full load for a given change in power factor increase as the reactance is increased, and to a lesser extent as the resistance is increased.

For loads below full load, only a slight error will be introduced if the voltage regulation is assumed to be proportional to the load. Typical curves giving load center voltage variation with load are shown in Figure 7. It is evident from these curves that a change in power factor at a fractional load produces much less effect on the voltage being held at the load center than the same variation in the power factor at full load.

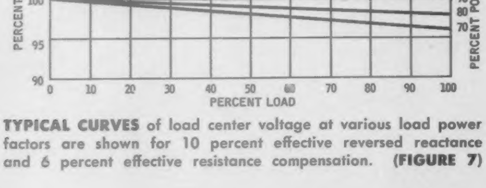
The amount of resistance compensation which is required to overcome the effect of the line reactance and maintain constant voltage at the load center is shown in Figure 8. This amount of resistance compensation increases both as the reactance increases and as the power factor of the load decreases.

## Method applied

**For any given installation the performance of the circuit may be determined from Figures 4 and 6. Values *R* and *X* are selected from Figure 6, based on the load power factor variation and permissible voltage variation. The value of *X* should be as great as is consistent with the permissible voltage variation.**

**The circulating current corresponding to 10 percent *X* is determined from Figure 4 for a corresponding power factor and ratio of *R/X*.**

**The value of the exciting current obtained from Figure 4 is to be corrected for band width, reactance, and number of machines in parallel by multiplying by the correction factors in Table I. This relation holds when the circulating current is proportional to the band width and inversely proportional to the reactance for the same value of *R/X*.**




**TYPICAL CURVES** of load center voltage at various load power factors are shown for 10 percent effective reversed reactance and 6 percent effective resistance compensation. **(FIGURE 7)**

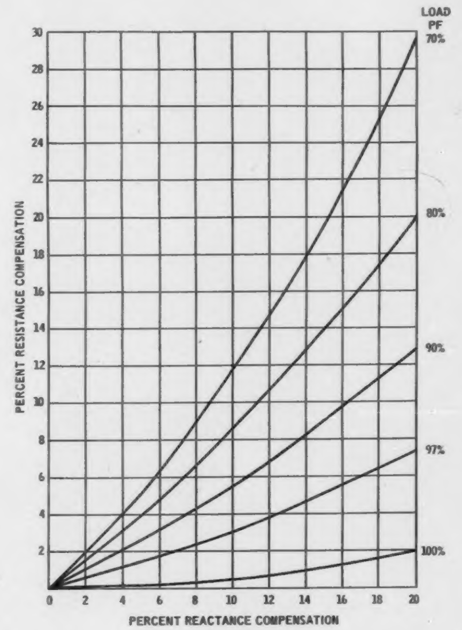
**TABLE I**

| Units in Parallel | Factor | Units in Parallel | Factor |
|---|---|---|---|
| 2 | 0.5 | 7 | 0.86 |
| 3 | 0.67 | 8 | 0.88 |
| 4 | 0.75 | 9 | 0.89 |
| 5 | 0.8 | 10 | 0.9 |
| 6 | 0.83 | ∞ | 1.0 |

When the power factor of the circulating current is not low, the circulating current corresponding to the selected ratio of *R/X*, from Figure 4, may be excessive. In some cases it may be possible to secure satisfactory operation by reducing the value of *R* to zero or even to a negative value. In such cases it may be desirable to set the no-load voltage of the voltage regulating relay at a higher value than normal in order to obtain the desired voltage at the load center at full load.

When the power factor of the load is very low and the circulating current power factor is high, satisfactory operation may be secured with positive reactance and reverse resistance compensation.

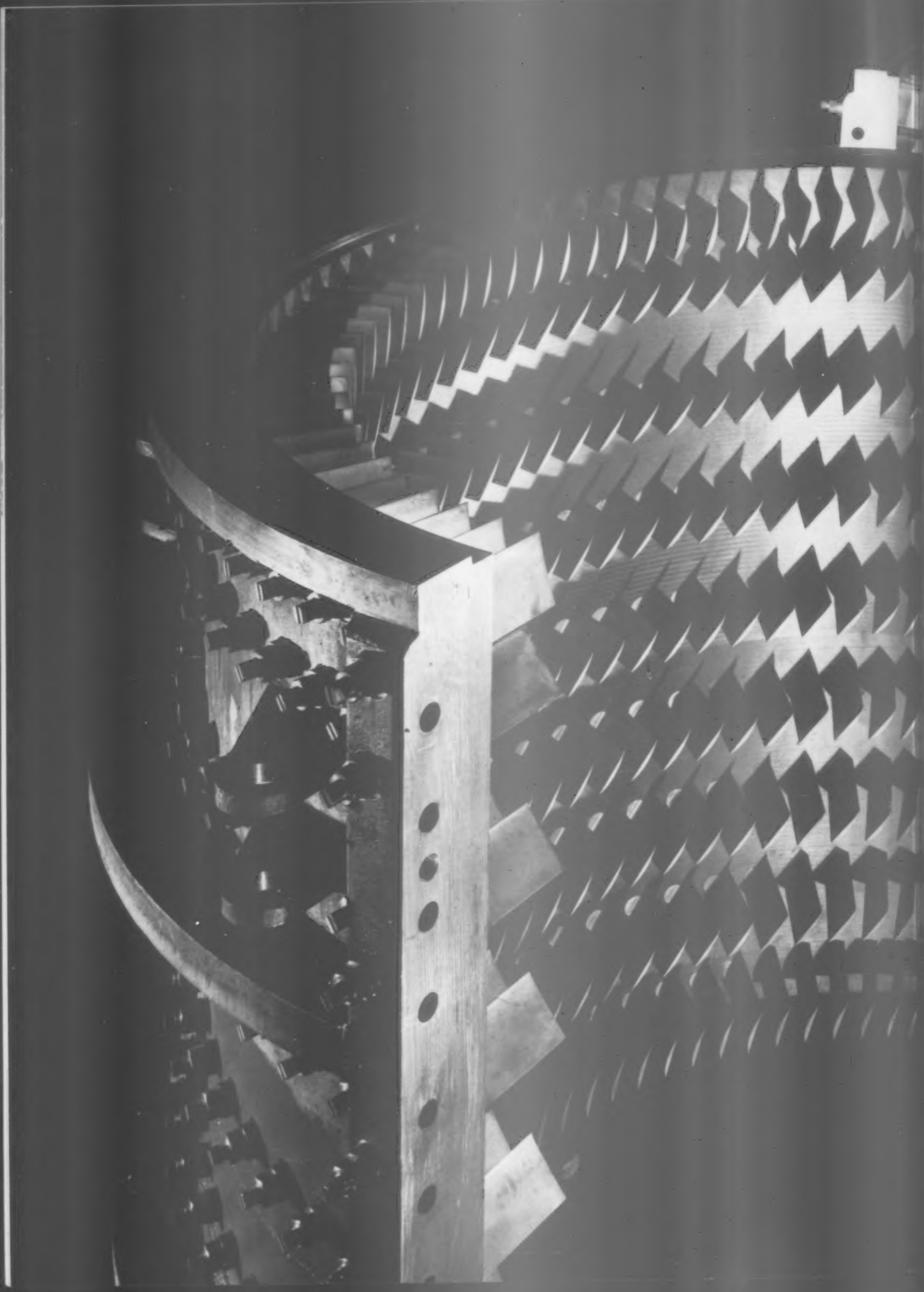
If satisfactory operating conditions as determined from the curves cannot be secured for a given application, one of the more complicated paralleling schemes should be chosen.

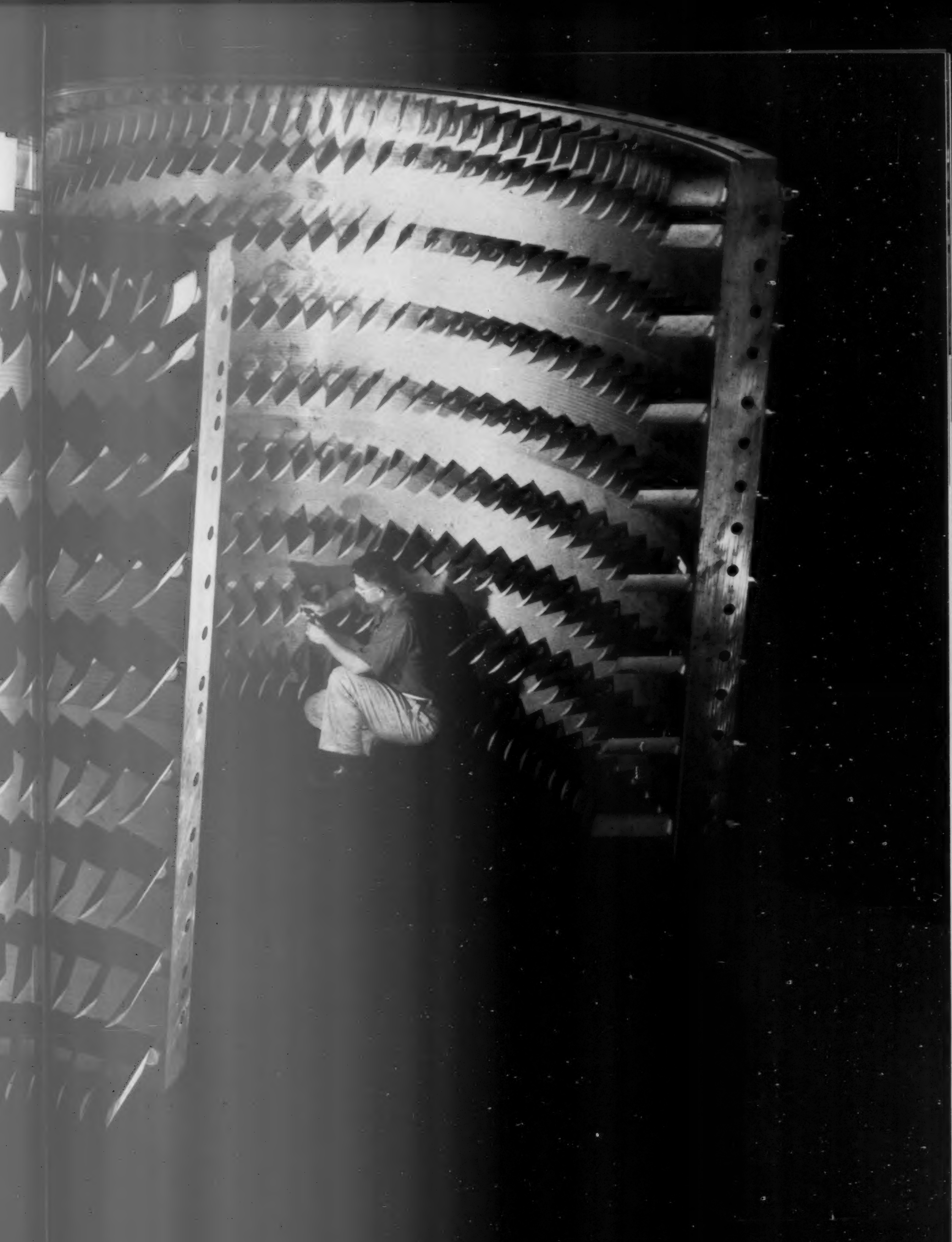


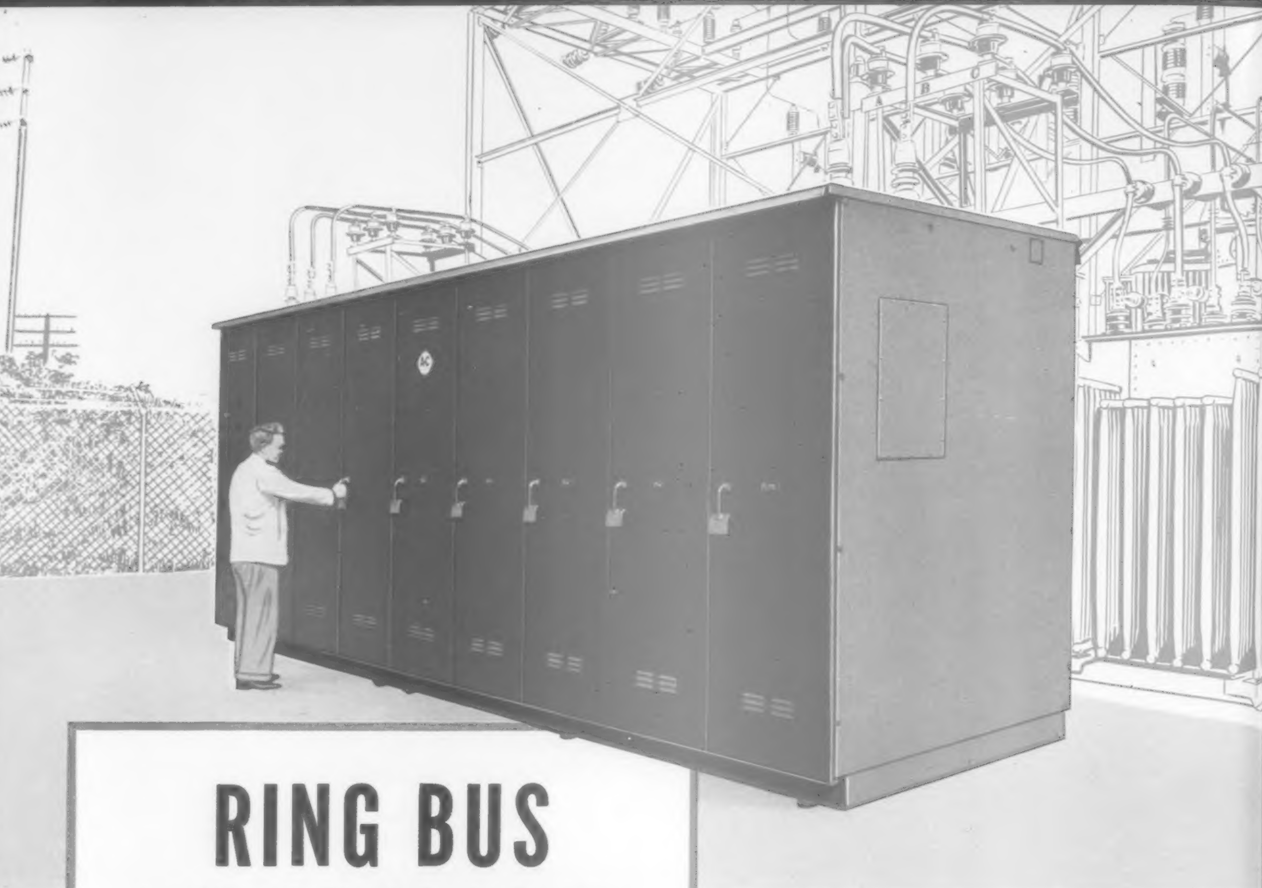

**REACTANCE COMPENSATION** and load power factor determine resistance compensation that is needed. **(FIGURE 8)**

**CYLINDER FOR A CYCLONE** — When fitted together and installed, these two halves of a 1,000-000-cfm axial compressor cylinder will help drive air at ultrasonic speeds.

*A-C Staff Photo by M. Durante*







# RING BUS

## In Metal-Clad Switchgear

by D. DALASTA
Switchgear Section
Allis-Chalmers Mfg. Co.

*Latest designs of standard metal-clad switchgear readily accommodate ring bus with its added reliability.*

THE EVOLUTION of factory-assembled switchgear reached a relatively stable period in the middle thirties with the introduction of "metal-clad" switchgear and its generally accepted characteristics:

(*a*) Withdrawal-type circuit breakers
(*b*) Fully insulated buses and connections
(*c*) Separate metal compartments for major components
(*d*) Safety interlocking
(*e*) Primary and secondary equipment separated by metal barriers
(*f*) Top, sides, and ends fully metal enclosed

Although the above basic characteristics have not been changed, the last two decades have seen innumerable important improvements in operation, safety, and maintenance features. Notable among these improvements are the extension of air magnetic breakers to 15 kv and 500 mva, the redesign of units to accommodate more equipment safely in less space and with less installed cost, and the changes to materials such as the recently developed self-extinguishing and flame retardant materials.

Until recently, however, the basic primary circuitry of each unit of metal-clad switchgear has remained unchanged, and units were installed adjacent to one another, with their buses connected to form one continuous main bus.

Due to the increasing use of ring-bus type of circuitry, special consideration has now been given to its requirements in standard metal-clad units.

### Slanting bus provides transition

Normally, a group of metal-clad switchgear consists of a number of circuit breaker and auxiliary units adjacently placed to form a continuous lineup. The primary bus extends in a straight line throughout the lineup, broken

only wherever bus sectionalizing units are placed. In a ring-bus design there can be no continuous straight-line bus, but it is desirable to make all units similar for standardization.

Ring-bus unit construction differs from conventional unit construction in that the stub buses run angularly from the front studs in one breaker unit to the rear studs of the adjacent unit in vertical-lift gear. With this bus arrangement standardized ring-bus units can be placed in a single lineup.

Furthermore, the ring tie may be enclosed within the switchgear as a straight continuous bus extending through all units to complete the loop. Extending the bus in this manner provides the following possibilities:

(*a*) Elimination of bus ducts or tie cables, which are usually necessary in physical arrangements of double-duplex, multiplex and similar type substations.

(*b*) Allows the application of three-transformer substations, which cannot be conveniently used in conventional secondary-selective type arrangements.

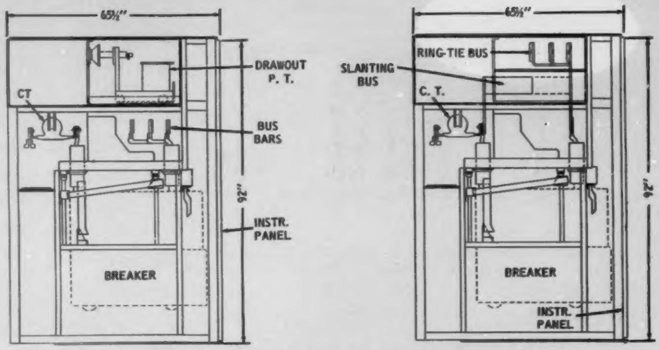
## Ring-bus unit design varies

The unit design for ring-bus construction varies with vertical-lift and horizontal drawout type of switchgear.

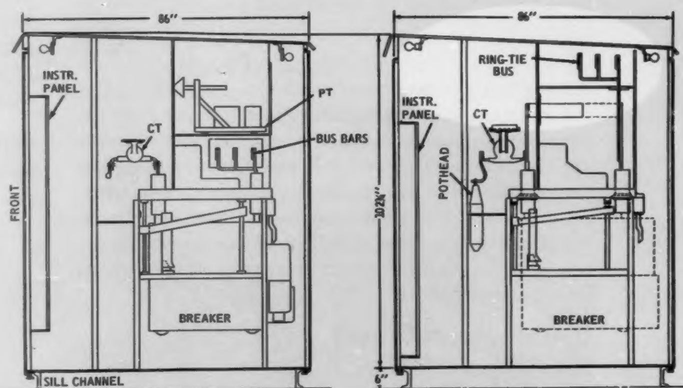
In vertical-lift metal-clad switchgear the slanting bus is located in the upper portion of the units, and standard unit widths are maintained for both indoor and outdoor construction. Figure 1 shows a side view of a 4.16-kv indoor unit, with the bus crossovers in a 26-inch high superstructure not exceeding standard instrument panel height. The ring-tie bus is also located in this same area.

For outdoor 4.16-kv vertical-lift construction, some manufacturers provide space for drawout potential transformers in the standard unit. Figure 2 shows how this space is utilized for the crossover buses and the ring-tie bus, allowing a complete ring bus to be accommodated, with no changes in overall unit dimensions. Figure 3 illustrates one of several 4.16-kv outdoor ring-bus groups which have been in service for several years in the Chicago area. The ring-tie bus can be seen near the top.

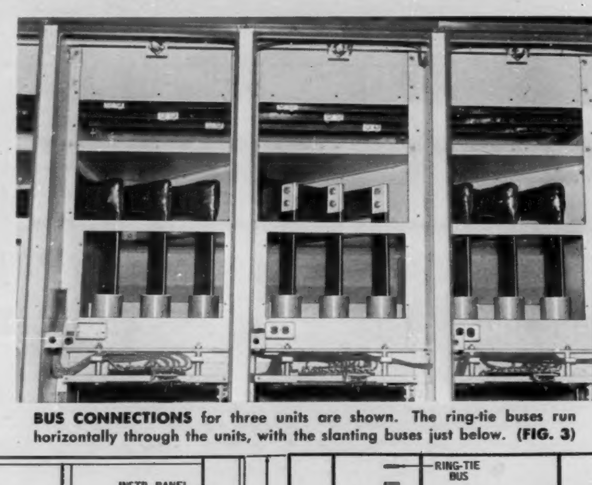
Horizontal drawout switchgear units are also adaptable to the ring-bus requirements, but the problem in these units is depth instead of height. The main bus in horizontal drawout metal-clad switchgear is at the lower rear portion of the unit when the breaker draws out from the front. The slanting bus extends from



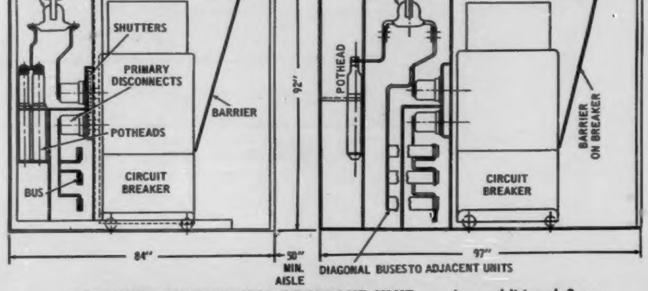

**RING-TIE** and slanting buses occupy same space as drawout potential transformer in a standard indoor unit. **(FIG. 1)**



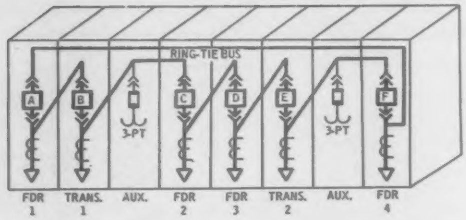

**STANDARD OUTDOOR UNIT** is modified to incorporate ring-tie and slanting buses in a similar manner. **(FIGURE 2)**



**BUS CONNECTIONS** for three units are shown. The ring-tie buses run horizontally through the units, with the slanting buses just below. **(FIG. 3)**




**STANDARD HORIZONTAL DRAWOUT UNIT** requires additional floor space to add the ring-tie and slanting buses within the unit. **(FIGURE 4)**




**RING-BUS ARRANGEMENT** in metal-clad switchgear is shown schematically to indicate the need for slanting bus. **(FIGURE 5)**

the normal bus position to one unit to a point directly behind this position in the adjacent unit, as shown in Figure 4. The location of the ring-tie bus is also indicated.

Ring bus can be incorporated into standard 13.8-kv horizontal drawout switchgear without increasing the external dimensions, provided all primary circuits leave the top of the units. This design is possible because the bus sectionalizing unit has the same dimensions as a standard unit. Such a ring-bus lineup would consist of a number of bus sectionalizing units located adjacent to one another. Shown in Figure 5 is a physical layout of a typical ring bus arrangement.

## Open ring normally used

Referring to the single-line diagram of a typical normally open ring-bus group shown in Figure 6, each incoming circuit is equipped with two phase (51T) and one ground (51N) induction overcurrent relays. These relays operate a hand-reset auxiliary relay (86-2) which:

(*a*) Trips transformer primary breaker.

(*b*) Trips transformer secondary breakers "*B*" and "*C*."

(*c*) Prevents bus-tie reclosing.

The transformer differential relays (87) and undervoltage relays (27) pick up another hand-reset auxiliary relay (86-1) which:

(*a*) Trips transformer primary breaker.

(*b*) Trips transformer secondary breakers "*B*" and "*C*."

(*c*) Closes tie breakers *A* and *D* (this function is prevented by previous operation of relay 86-2).

Feeder overcurrent relays (51) trip both adjacent circuit breakers through a self-reset auxiliary relay (51X). Suitable devices are also included to provide the usual control, interlocking and instrumentation requirements. Reclosing relays can be applied on feeders without undue complications.

## Ring bus has advantages

In general, ring-bus arrangements in metal-clad switchgear can offer the following advantages:

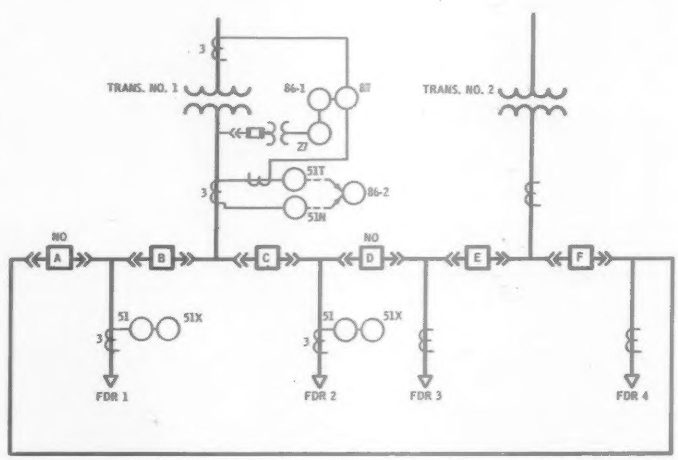
(*a*) Each feeder is supplied by two buses.

(*b*) Only one circuit breaker is required for each circuit.

(*c*) Any breaker can be removed from its unit without disrupting continuity of service.

(*d*) Any portion of switchgear bus can be de-energized by dropping only one circuit.

(*e*) Additions can be made at either end by dropping only one circuit.




**SINGLE-LINE DIAGRAM** includes the necessary relays to protect the transformers and secondary circuits. **(FIGURE 6)**

(*f*) Each set of feeders and its supply transformer can be operated separately, reducing required interrupting capacity of breakers. Feeders are automatically picked up by adjacent transformers.

(*g*) More advantageous physical arrangement of units is possible in many cases.

(*h*) The entire ring is usually included within the switchgear group; this eliminates tie cables and connecting bus runs.

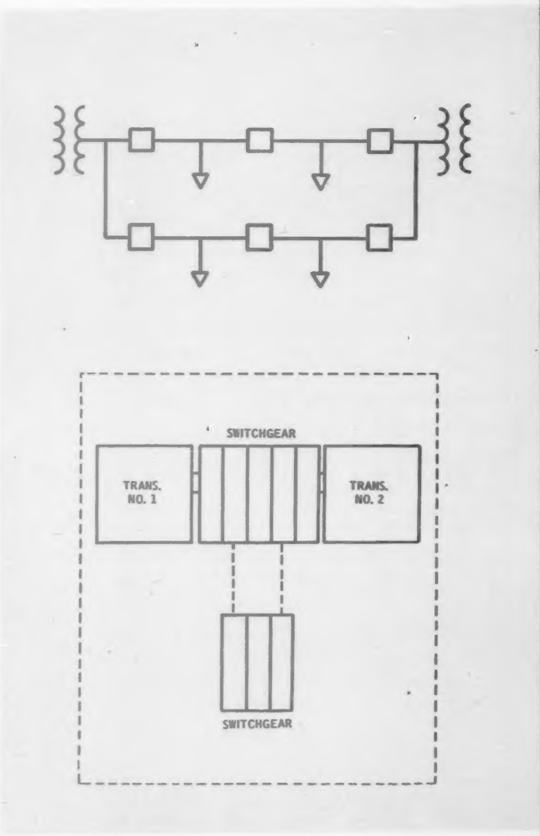
Removal of individual breakers for maintenance without disrupting service continuity is very important. The use of a spare breaker limits the outage time to only a few minutes, but sometimes even this short period cannot be tolerated. Bypass disconnect switches built into the switchgear for this purpose are expensive. Externally mounted feeder bypass switches are quite often unsafe, inconvenient, unattractive, or space consuming. Breaker removal for inspection and maintenance is no problem with ring-bus circuits.

## Closed ring applications limited

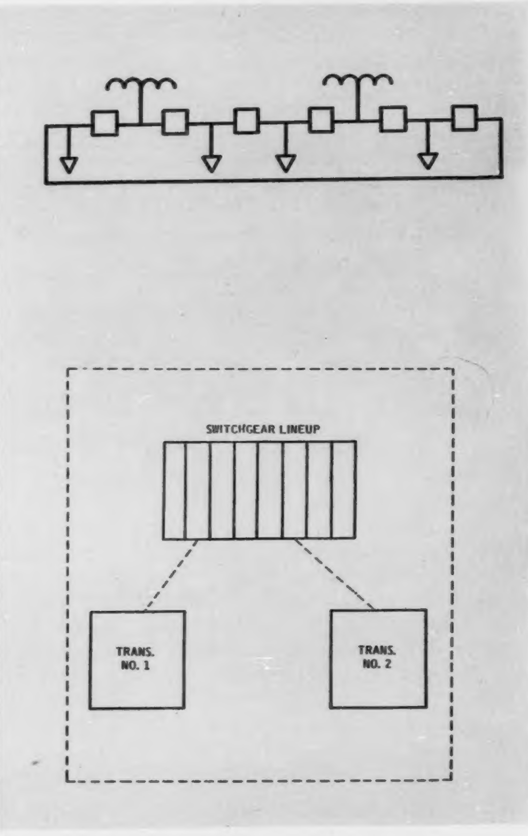
Since supply transformers operate in parallel, circuit breakers of higher interrupting capacities are required for normally closed ring-bus applications. For this reason, closed ring schemes are generally confined to those placed where even momentary interruptions of service are undesirable. This would correspond to the conventional spot-network substation. Installations of this type should be limited in capacity, to reduce breaker size requirements. Moreover, most of the ring-bus advantages previously listed also apply to closed ring schemes.

## Overall bus differential protection possible

Due to the number of stub buses in any ring-bus scheme, individual bus differential relaying is never considered. Overall bus differential protection is possible in the same manner as in conventional arrangements; however, except in the larger substations, it is not generally regarded as economically practical. Bus differential protection can automatically be obtained by placing all current transformers within the ring and connecting the line relays to paralleled sets of bus current transformers. This arrangement is used in general practice on high voltage ring buses but requires a total of six current transformers per circuit. Physically locating these CT's within the ring is difficult in metal-clad switchgear and usually results in placing




**DOUBLE-DUPLEX ARRANGEMENT** requires two separate groups of switchgear. **(FIGURE 7)**




**RING-BUS** switchgear presents a single lineup, cable or bus connected to transformers. **(FIG. 8)**

CT's where they are not readily accessible. Also, current transformer primaries have to be rated for bus currents. This introduces the need for auxiliary transformers or separate additional current transformers in each feeder circuit.

The application of ground-fault bus differential relaying schemes is not affected by ring-bus designs.

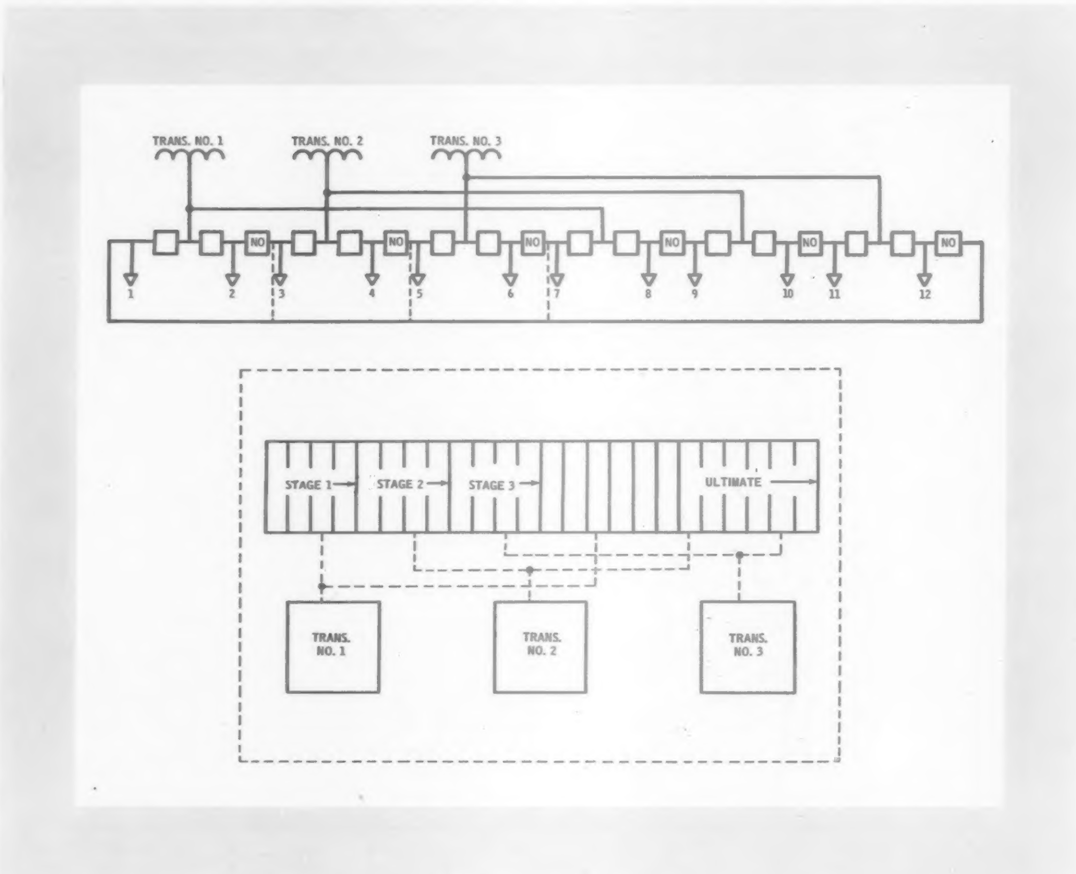
Control power and potential transformers are connected directly to the incoming line circuits. Unlike conventional designs, bus PT's cannot be used for lack of a common feeder circuit bus. The usual equipment is required for the transfer of control power transformer secondary circuits.

## Ring-bus and double-duplex schemes compared

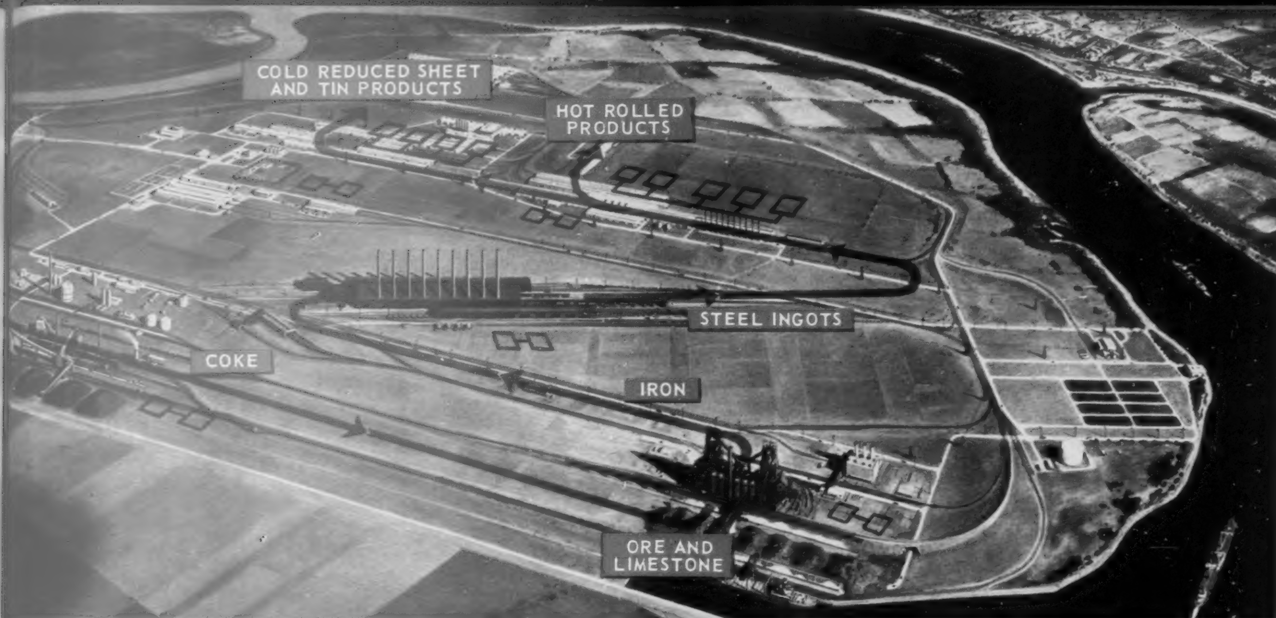
One of the simplest ring-bus arrangements is electrically identical to the conventional double-duplex substation. While the ring-bus design consists of a single lineup, with transformers either cable or bus connected, the double-duplex differs in that it is usually arranged in two groups of switchgear, with two transformers throat connected to one group. Figures 7 and 8 show the two layouts. Each has its own advantages relative to location of transformers and space requirements.

Figure 9 shows a ring-bus arrangement which can initially incorporate one transformer and two feeders. Additional sets can be added as required. After three transformers and six feeders have been installed, further expansion can be either of two schemes: Additional sets of transformers and feeders can be added; or, as shown in Figure 9, transformers can be used to supply four feeders instead of two. In the latter case, the original transformers of perhaps 3750 kva are replaced with 7500-kva units. It is doubtful whether any other type of substation can provide the overall advantages obtained by this scheme. The successive stages of equipment additions are indicated.

The recent development of standardized metal-clad switchgear units for use in ring-bus type substations will enable station designers to again turn their eyes to the possibility of using ring buses. They will find, in many instances, that this is one more way to improve continuity of service to the customer.




**FLEXIBILITY** may be obtained with ring-bus switchgear. Additional feeders and transformer capacity may be added. **(FIG. 9)**




**SEGMENTS** of this integrated steel mill are tied together by the thread of continuity called materials handling and powered by rectifiers indicated with color squares.

# 25,000 Kw of DC Power MOVE MATERIALS at FAIRLESS WORKS

by **D. B. SCOTT**
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**and**
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FAIRLESS WORKS, the new United States Steel Corporation plant at Morrisville, Pennsylvania, is a completely integrated steel mill. It is designed to receive iron ore, coal and limestone either from rail shipments or from ocean-going vessels docked in the Delaware River, and to turn these raw materials into finished steel forms and shapes for shipment overland or by water to the many ultimate users.

Throughout this integrated process of making finished steel, individual segments of the steel mill are tied together by materials handling equipment. A large part of this equipment is dc powered from 19 excitron mercury-arc rectifier substations placed at load centers throughout the plant. These substations, with total capacity of 25,000 kw, supply 100,000 amperes of 250-volt dc power.

Large numbers of dc motors are used in this steel mill on cranes, ore bridges, transfer cars, scale cars, door machines, valve operators, conveyors, machine tool drives, coke pushers, and quenching car locomotives because they are capable of extremely high starting torques and are adaptable to frequent starting and stopping. They also offer wide-range speed adjustment readily variable in fine steps. In addition, dc power is best suited to produce the desired controllable magnetic pull for lifting magnets, magnetic pulleys and magnetic chucks.

While industrial applications of mercury-arc rectifiers are usually additions to existing dc systems or replacement of obsolete rotating machines, at Fairless Works rectifiers were applied initially on a mill-wide basis to supply constant potential direct current power. This enabled the engineers for both the steel company and the manufacturer to take full advantage of the many favorable characteristics of rectifiers for steel mill operation, and at the same time provide low installation, maintenance and operating costs. Also, many particular features to insure reliable continuous operation of the rectifiers were introduced.

A completely integrated system was designed, utilizing dc networks and double-ended substations to provide the absolute continuity of dc power so essential to the economical production of steel. Placed at load centers for close connection to the machines they supply, the rectifier substations are tied together in networks to allow transfer of dc power between load centers, permitting rectifiers to be shut down for servicing without power interruption.

## Materials handling in the steel-making area

The materials handling process begins at the dock area where the ship unloaders and ore bridges; the storage yards for ore, coal and limestone; the blast furnaces; and the coke plant are located. Two 1500-kw rectifiers in a double-ended substation near the blast furnaces supply power for the two blast furnaces, ore unloaders, ore bridges, transfer cars, and scale cars. Provisions have been made for additional rectifiers and a dc tie bus for connecting the rectifier substations when load increases as future blast furnaces are added and the ore docks extended.

At the coke plant, two 500-kw sealed tube rectifiers, connected end to end, supply power for coke pushers, coke trains, and other machinery at the two 87-oven batteries.

Molten iron from the blast furnaces is carried by train to the open hearth area where it is made into steel. There are nine open hearth furnaces capable of a combined output of 2,200,000 net tons of steel annually. Two excitron


**BOAT UNLOADERS** and bridge crane feed the blast furnaces with raw materials brought into this boat slip. **(FIGURE 1)**

**FINISHED COKE,** forced from an oven by a coke pusher, tumbles into a quenching car. **(FIGURE 2)**

rectifier substations near the open hearths provide 3000 kw of dc power necessary for operating vital materials handling equipment, including hot metal cranes, charging cranes, pouring cranes, mould yard cranes, stock yard cranes, and the pig machine.

Steel is produced at the open hearth furnaces in a wide variety of carbon and alloy grades, and transferred to the hot mill area for processing into shapes and forms. After being heated in soaking pits, ingots are carried to the slabbing mill where they are either rolled into slabs for the hot strip mill or transferred to the blooming mill.

Slabs for the hot strip mill are heated in continuous furnaces and then fed to the mill for rolling into strips of various thicknesses and widths.

Steel for the blooming mill is carried directly from the slabbing mill to the 40-inch reversing blooming mill. Here it is rolled into billets for shipment, or carried to the 30-inch and 21-inch billet mills for further reduction. From the 21-inch billet mill, some steel is carried to the 10-inch bar mill for processing into smaller shapes.

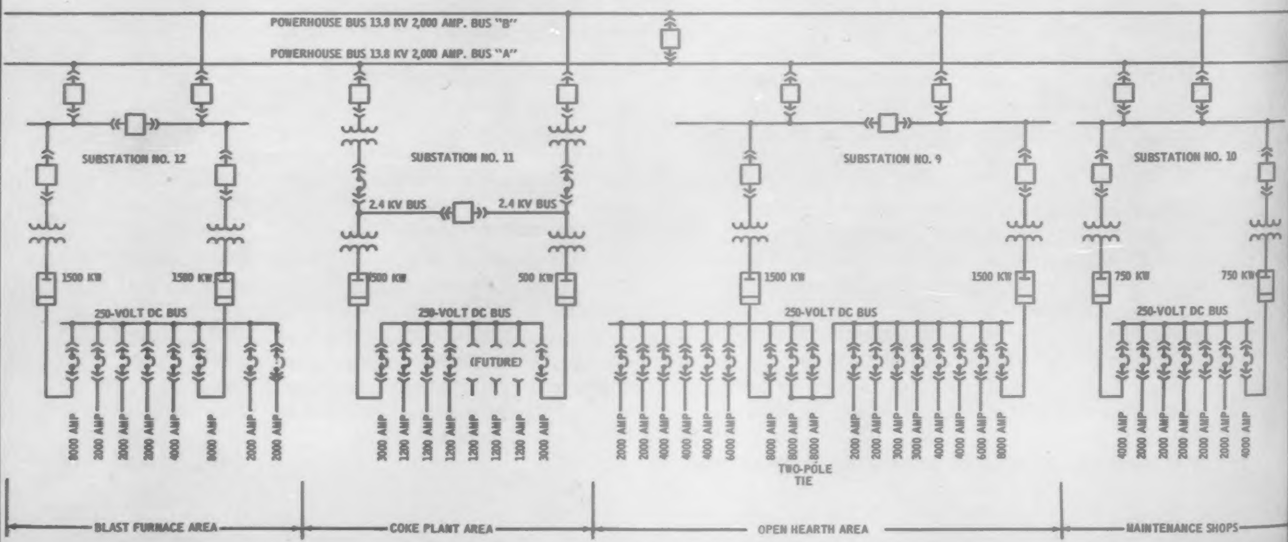
Power for the cranes and conveyors in the hot mill area is supplied by seven 1500-kw excitron rectifiers. Single rectifier substations are located at the 45-inch slabbing mill, the 40-inch reversing blooming mill, and the 10-inch bar mill. Double-ended rectifiers are located at the 30-inch and 21-inch billet mills and the hot strip mill motor room. Except for the hot strip mill units, all of the hot mill rectifiers are connected through a tie bus. The hot strip mill units are rated to provide 70 percent standby service, and connected end to end to a common feeder bus. In this way, power continuity for the continuous processing of steel in the hot strip mill is assured.

Most of the steel processed in the hot strip mill is transported to the Sheet and Tin Mill for further finishing. Here the steel is either prepared for sale as hot rolled steel, further processed and rolled for sale as cold rolled steel, or made into tinplate. The Sheet and Tin Mill contains a sheet temper mill, a 4-stand cold reduction mill, a 5-stand cold reduction mill, and a two-stand tin temper mill and electrolytic tinning line. At each of these locations is a 1500-kw excitron rectifier substation, and all four are connected to a common dc tie bus.

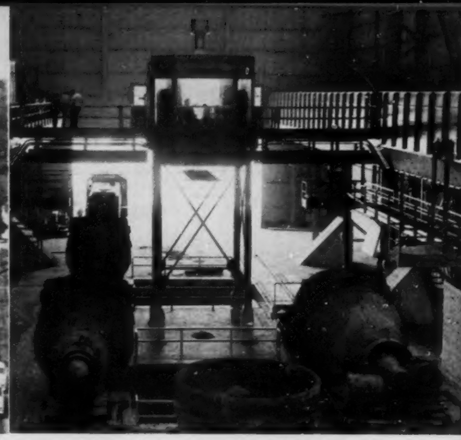
Fairless Works has a completely equipped central maintenance area, with shops for machining rolls, repairing mechanical and electrical machinery, and a diesel shop for maintenance of rolling stock. Dc power for the central maintenance area is supplied by two 750-kw excitron substations, connected end to end, supplying a common bus.

## Designing the dc system

Ample provisions were made in the dc system to allow for expansion with future growth of this mill. Ultimate expansion of the various areas will increase the requirements for dc power and, as more rectifiers are added, additional



FROM THE OVENS, coke is conveyed to the blast furnace area shown in the upper right-hand corner. (FIG. 3)



MOLTEN IRON is poured from hot metal cars to ladles, carried to open hearths by cranes and transfer cars. (FIG. 4)

tie buses can be employed for enlarging the dc networks.

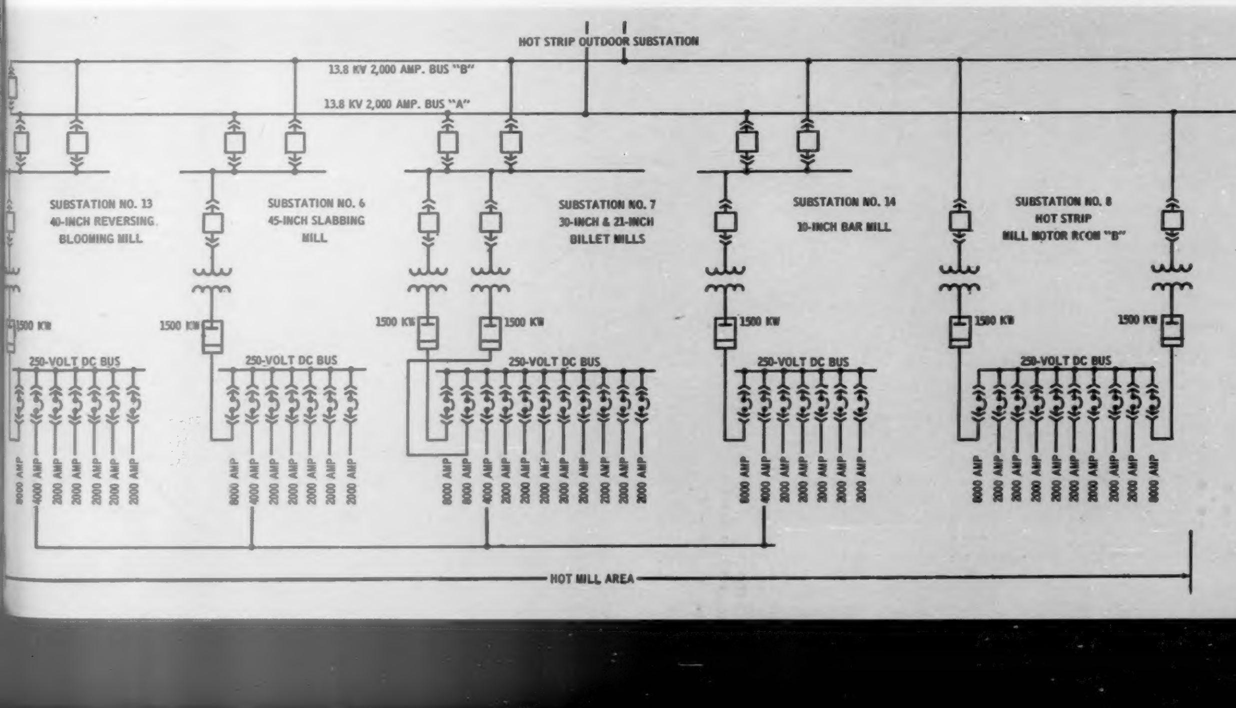
The nature of the dc load made excitron rectifiers the logical choice for dc power supply. Power requirements are constantly varying and cause the dc current to swing from an average loading of perhaps 30 to 40 percent to peak values as high as 200 percent of rated capacity. Excitron rectifiers have an inherently high efficiency at all loads, unusually small no-load losses and the ability to handle extreme load swings easily.

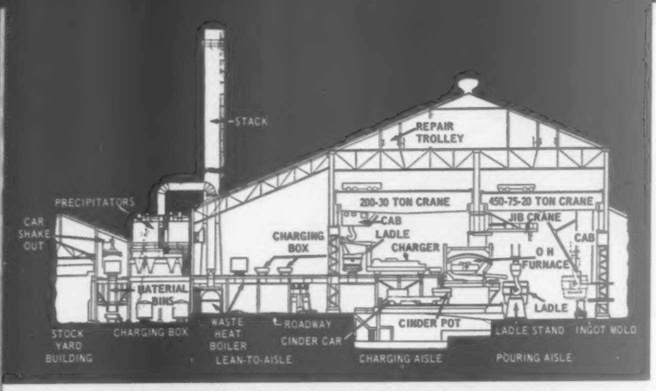
The excitron substations are designed for unattended operation, are completely self-protecting, and as nearly automatic as is desirable for this application. Each substation is equipped with a master control switch for starting and stopping the rectifier. Closing the master control switch causes the rectifier auxiliaries to be energized, and if all auxiliary circuit conditions are correct, the ac circuit breaker closes. This causes 250 volts dc to appear across the rectifier terminals, which in turn closes the cathode breaker. If any condition in the rectifier circuit is not correct, the starting cycle will not complete itself, and the fault will be indicated on a 12-position annunciator. The rectifier substation is shut down by opening the master control switch.

Each rectifier feeds its load through a group of automatic-reclosing, load-measuring type dc feeder circuit breakers. Each of these breakers, indicated on the single-line diagram, is equipped with an adjustable overload trip which will remove the feeder circuit from the rectifier bus in case of a fault, without disturbing the rectifiers or the other feeder circuits on the rectifier bus. To make the dc feeder arrangement completely selective, the rectifier cathode breakers do not have overload trips, but are equipped only with reverse current relays. Thus the cathode breaker will open only on a rectifier fault, forcing the feeder breakers to furnish complete primary load protection. The rectifier ac breakers further protect against faults in the rectifier circuit by means of instantaneous trips, and in the event of a failure of the feeder breakers to clear a fault they will protect the rectifier by means of inverse-time trips. The instantaneous trips are set at 700 percent, and the inverse-time setting is 200 percent of rated current.

The load-measuring reclosing feature of the dc feeder circuit breaker functions to measure the resistance of the load after a feeder circuit breaker has opened on a fault. As long as load resistance remains low enough to indicate the fault has not been cleared, the feeder breaker is prevented from closing. When load resistance becomes high enough, the feeder breaker recloses automatically.

Metallic underground structures, building members, and pipes may be damaged by electrolysis if stray direct currents flow in the area. Considerable damage of this type may result from grounds in a dc system.






**CROSS SECTION** of open hearth building shows cranes for charging, hot metal, pouring — all typical dc loads. **(FIG. 5)**

Since the Fairless Works is built on moist soil that is apt to be highly conductive most of the time, an ungrounded dc system was selected. The plant layout is so engineered that any dc grounds can be easily detected and traced, thereby lessening the danger of possible damage to the plant from this cause.

Because of the large number of rectifier transformers used, one-half were designed with delta-connected ac windings and one-half with wye-connected ac windings. The effect of this arrangement on the ac distribution system is the same as if 12-phase dc windings had been used in each rectifier transformer. A 2 percent net gain in power factor is realized over an equivalent six-phase system.

Provisions were made to permit quick and easy transformer replacement. Each transformer is mounted on broad-flanged wheels to make moving and positioning easier. The wheels are locked in one position, restricting movement to only one direction. However, by jacking up the transformer and rotating the wheels 90 degrees, they can be locked in a second set of wheel bearings for movement at right angles to the first direction. Broad-flanged wheels allow the transformers to be moved on a flat surface where rails are not available.

A flanged terminal compartment and pothead for entrance of the 13.8-kv line also facilitate transformer replacement. The flange is placed between the pothead and the terminal portion of the compartment. Through a handhole in the side of the compartment, terminals can be disconnected, the flange unbolted, and the transformer rolled away without disturbing the pothead or conduit.

Lightning arresters on the ac windings protect the transformers from line voltage surges originating within the system itself. A no-load tap-changing mechanism provides four 2½ percent full capacity steps, two above and two below normal.

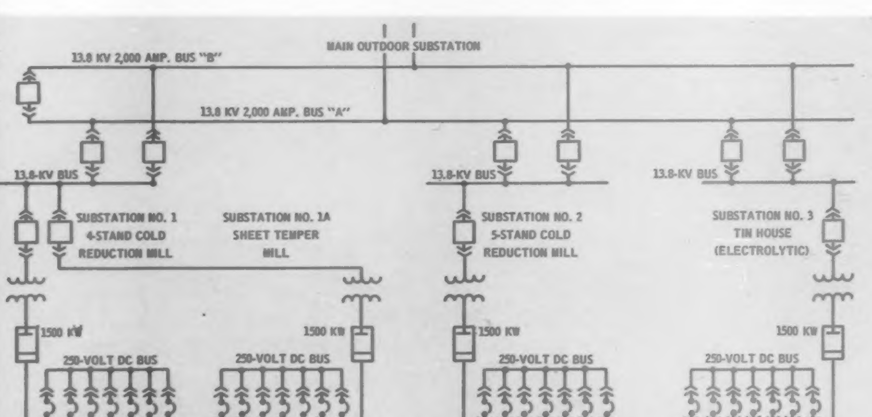
## Devices protect equipment and locate trouble

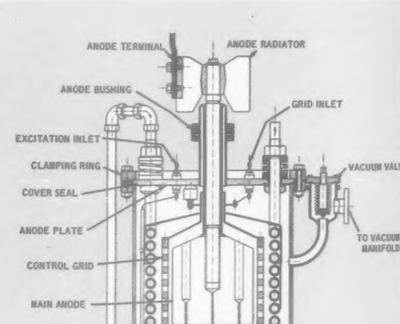
A full complement of protective devices are installed in the dc power system at Fairless Works. These devices fall into two categories: those primarily designed to protect the equipment, and those used principally to assist in maintenance and locating trouble. Overload, overtemperature, water pressure, reverse current, reverse phase, and undervoltage relays are included in the first category. The second group includes vacuum measuring devices, annunciator, water pressure and temperature gauges, sight gauges, indicating instruments, and various transfer switches for testing and changing from automatic to manual control.

Each excitron tube has a thermostat located in the outlet side of its cooling coil. If the outlet water temperature of any of the tubes rises above the temperature setting of the thermostat, the dc rectifier breaker will trip, but the water pump will continue running. As soon as the water temperature drops below the prearranged setting of the thermostat, the dc breaker will automatically reclose. This arrangement protects the rectifier from extended overloads above the 125 percent 2-hour rating, while automatic reclosing of the dc rectifier breaker provides a quick way of restoring power to the mill. The excitron tubes are also protected against water pressure failure in a similar manner by a pressure switch in the recirculating system.

If an excitron unit is overloaded prior to shutdown and the anode temperatures are above normal, cooling water will continue to circulate and the pump will operate after shutdown until tube temperatures return to normal.

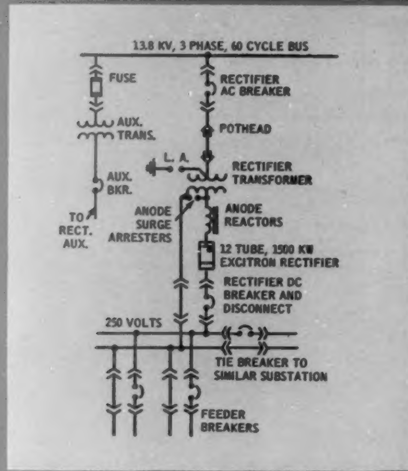
A single-phase and reverse-phase relay is connected to the low voltage side of the auxiliary power transformer at each excitron substation to prevent reverse rotation or



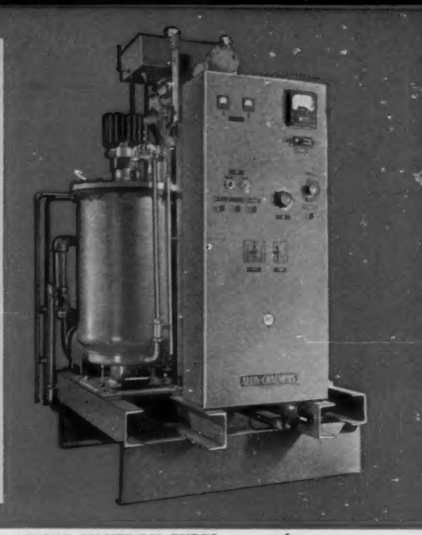




**INTERNAL COOLING** coil, low arc drop and continuous excitation are features of the rectifier tubes. **(FIGURE 9)**

ANODE CABLES from the transformers come through the wall to this 12-tube rectifier frame and control compartment. (FIG. 6)




POWER CIRCUITS with protective features, open-ended dc bus and bus tie are diagrammed for this typical 1500-kw excitron substation. (FIGURE 7)



SPARE EXCITRON TUBES are made available at all times by this two-tube conditioning unit. (FIGURE 8)

single-phase starting of the rotary vacuum pump and water pump motors. It will also shut down the rectifier on undervoltage by tripping the ac and dc rectifier breakers if the auxiliary power fails. The drop-out or undervoltage setting of the reverse-phase relay is set at a low value to permit the rectifier to ride through minor voltage disturbances.

Each rectifier transformer is protected from overtemperature and low oil level. A dial-type thermometer and a dial-type oil level gauge are connected to sound an alarm and trip the ac rectifier breaker.

The control compartment of each rectifier has several transfer switches which are used for test and maintenance purposes. Automatic-to-manual transfer switches are included for excitation, water heaters, water pump, rotary vacuum pump, and the voltage regulator. Output voltage of the rectifier may also be controlled manually with a separate grid-bias rheostat.

An annunciator on the excitron control compartment has 12 separate drops to locate the source of any difficulty that may arise, and an alarm relay to give a signal in the powerhouse whenever a rectifier is shut down.

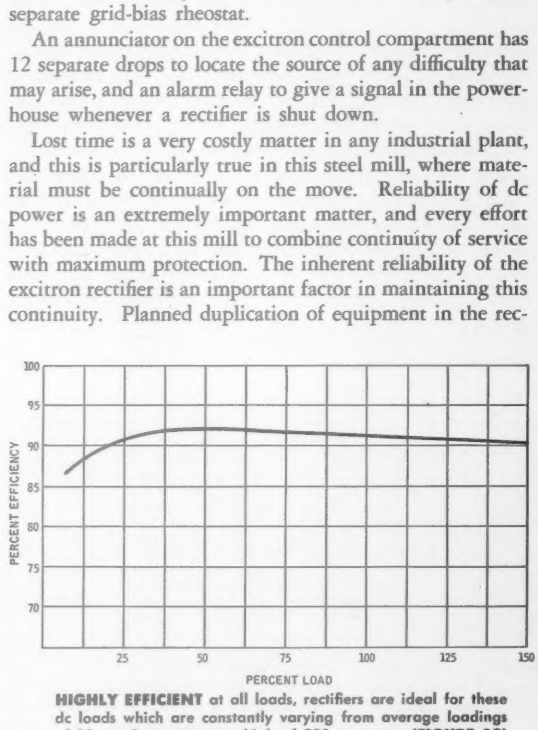
Lost time is a very costly matter in any industrial plant, and this is particularly true in this steel mill, where material must be continually on the move. Reliability of dc power is an extremely important matter, and every effort has been made at this mill to combine continuity of service with maximum protection. The inherent reliability of the excitron rectifier is an important factor in maintaining this continuity. Planned duplication of equipment in the rectifier substation was employed to the fullest extent, so that most items are completely interchangeable and the maintenance procedures uniform throughout the mill. With the exception of the two 500-kw rectifiers in the Coke Plant for which a spare sealed tube is maintained, all of the substations use identical pump-evacuated rectifier tubes.

In order that spare tubes will always be available, a two-tube conditioning unit was installed in the central maintenance shop, where two pump-evacuated rectifier tubes are maintained as spares. In event of an emergency, a spare can be placed where needed, the faulty tube repaired when time permits, then placed on the conditioning unit for retention as a spare.

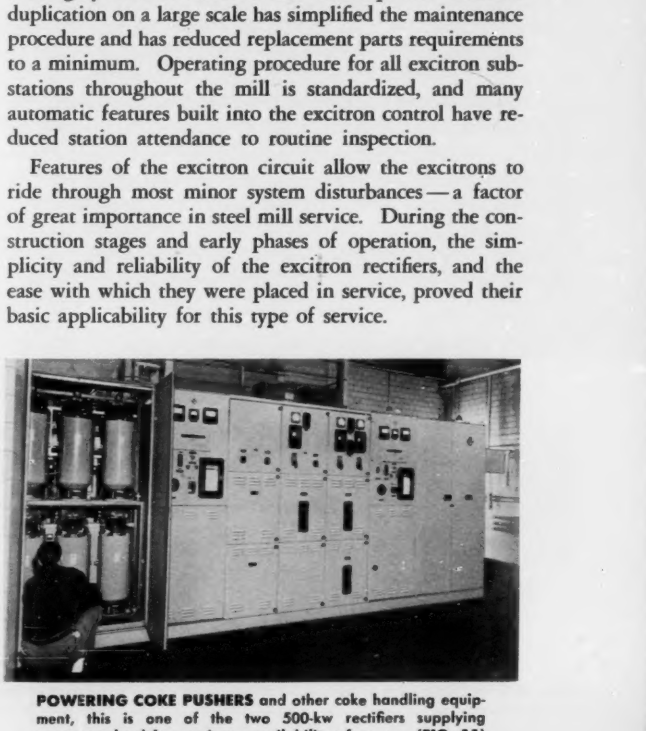
## Excitron rectifiers prove reliable and efficient

The excitron rectifier has provided an extremely reliable and highly efficient source of 250-volt dc power. Planned duplication on a large scale has simplified the maintenance procedure and has reduced replacement parts requirements to a minimum. Operating procedure for all excitron substations throughout the mill is standardized, and many automatic features built into the excitron control have reduced station attendance to routine inspection.

Features of the excitron circuit allow the excitrons to ride through most minor system disturbances — a factor of great importance in steel mill service. During the construction stages and early phases of operation, the simplicity and reliability of the excitron rectifiers, and the ease with which they were placed in service, proved their basic applicability for this type of service.




HIGHLY EFFICIENT at all loads, rectifiers are ideal for these dc loads which are constantly varying from average loadings of 30 to 40 percent to a high of 200 percent. (FIGURE 10)



POWERING COKE PUSHERS and other coke handling equipment, this is one of the two 500-kw rectifiers supplying a common load for maximum availability of power. (FIG. 11)

# Betatron Application Extended with NEW ELECTRON BEAM TUBE


by **D. T. SCAG**
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Allis-Chalmers Mfg. Co.

and

**T. H. ROGERS**
Director of Engineering
Machlett Laboratories

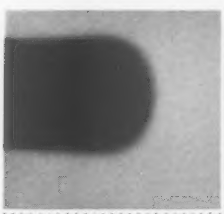

*Well established in X-ray therapy and as a valuable inspection tool for heavy industry, the betatron now becomes an important source of direct, high energy electrons.*

ELECTRONS accelerated within an electron beam donut tube recently developed are peeled from their orbit and fired through a beryllium window as an electron beam. This tube, designed for use in the 22-mv betatron, makes the betatron a more valuable research tool by permitting more precise control of beam penetration than ever before possible. Interchangeable with the X-ray emitting tube, this new tube emits a beam having several characteristics which make it especially valuable for both treatment and research on living tissue.

## Electron beam characteristics

With this new tube, exposure to radiation can be restricted more closely to tissue requiring treatment because penetration of its electron beam ceases abruptly at a definite depth, as indicated in Figure 1. In contrast, Figures 2 and 3 indicate the high initial intensity and the gradual falling off of intensity when X-ray emission is used. These patterns were produced on film inserted into presdwood phantoms exposed edgewise to the electron and X-ray beams. A slight curvature of the actual trajectory and the electron beam's spreading cross section due to scattering caused by the window and intervening air are indicated by the pattern of film exposures shown in Figure 4.

In making these exposures, the single radiation burst technique was used. Effective intensity was estimated as 20 million roentgens per second, lasting about one microsecond. In normal operation, the betatron with this tube



**FILM EXPOSED** edgewise to 17.3-mv electron beam in a phantom shows uniform intensity ceasing abruptly at definite depth. **(FIG. 1)**

**23-MV X-RAY BEAM** gave this pattern showing a more gradual falling off of intensity than the 200-kv test. **(FIG. 2)**

**EXPOSURE** to 200-kv X-ray beam shows high surface intensity of conventional X-rays with a rapid drop off.* **(FIG. 3)**

produces 180 such bursts per second. The percentage of radiation achieved at various depths with X-ray and electron beam emissions are compared in Figures 5 and 6.

At the present stage of development, the normal intensity at one meter is approximately 2000 roentgens per minute when the betatron is operating at an energy setting of 17 mv. Quantitative measurements of intensity were made with a 250-roentgen Victoreen thimble encased in a 4mm wall lucite chamber.

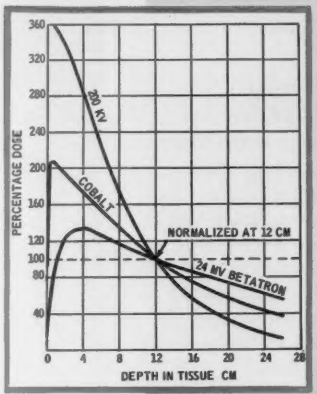



FIGURE 5

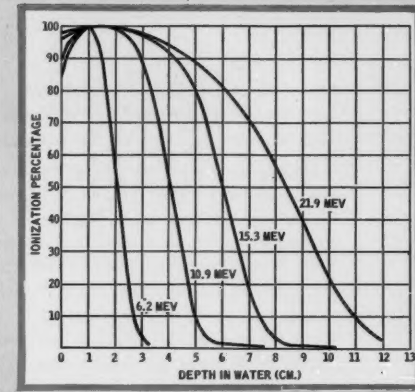
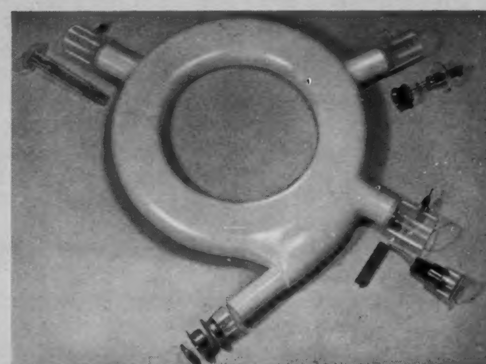



FIGURE 6

**DEPTH DOSE DISTRIBUTION** for cobalt, 200-kv and 24-mv X-rays are compared in Figure 5 . . . for direct electron beams of various energies, in Figure 6.*

The electron beam donut shown in Figure 7 is distinguished from the already standardized X-ray donut by a peeling mechanism and a thin window of low density material through which the electrons emerge. The peeling mechanism is a laminated "permendur" magnetic shunt with a longitudinal slot placed tangential to the orbital circumference of the donut. It provides a magnetic-field-free region within the slot, into which the electrons enter when an orbit-expanding pulse is applied. Once in this field-free space, the electrons no longer move in a circular path but tend to travel in a line tangential to the previous orbit.

The peeler assembly, including the laminated iron magnetic shunt with its supporting and adjusting system, is shown in Figure 9. This assembly must be inserted, aligned, held in alignment and sealed into the peeler housing portion of the donut in very close approximation to its correct position.

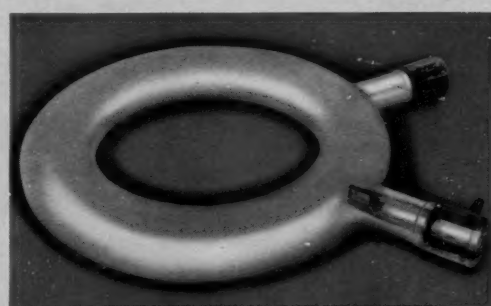


**ELECTRON BEAM TUBE** components: porcelain body, and (clockwise from upper left) injector, ground connection with barium getter, peeler, window assembly. **(FIG. 7)**

## Building tube posed problems

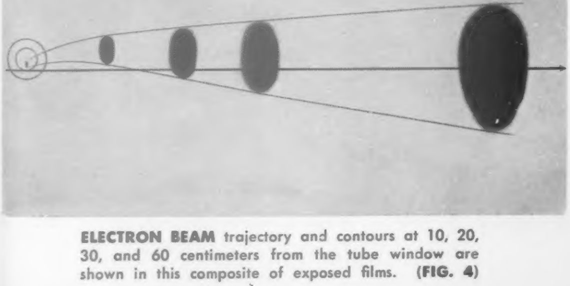
Modification of the standard X-ray donut to an electron beam tube presented numerous problems. The most difficult single element to design and construct was the electron beam window. When selecting the window material, minimum energy loss and electron scattering required that a thin section of low density non-magnetic material be used. In addition, the material had to permit a permanent vacuum-tight seal while withstanding the high temperatures necessary for outgassing the sealed-off tube and the force of atmospheric pressure over an area approximately 1 inch in diameter. Previous pump-connected tubes have used aluminum windows .001 inch thick cemented in place over an opening in the donut wall. This arrangement could not, of course, be used in a sealed-off tube.

Windows of thin beryllium sheets have been used to minimize absorption of the soft radiation from certain



**SHOWN IN PHANTOM** is the injector of the standardized 24-mv betatron X-ray donut tube. **(FIGURE 8)**

* Films shown in Figures 1, 2, and 3 and information for Figure 6 from University of Illinois, College of Medicine.



**ELECTRON BEAM** trajectory and contours at 10, 20, 30, and 60 centimeters from the tube window are shown in this composite of exposed films. **(FIG. 4)**

**ELECTRONS** are peeled from their circular orbit by this laminated permendur peeler shunt. **(FIGURE 9)**

extremely low voltage X-ray tubes. Because of its low density and high mechanical strength, beryllium was selected as window material for this high energy electron beam.

However, calculations indicated that energy absorption and scattering effect of the approximately 1mm thick window, generally used in X-ray tube structures, would be undesirably large for electrons in the energy range of 5 to 25 million volts. By holding the window thickness to approximately 0.5mm, or .020 inch, corresponding to a cross-section density of about 0.9 mg per sq mm, electron energy loss of about 0.2 mv and a scattering angle at 20 mv of about 0.1 degree were achieved.

Techniques already employed for incorporating beryllium windows in low voltage X-ray tube envelopes were refined and adapted for installing the much thinner window in the ceramic donut wall. The first step was to mount the beryllium disc in a bezel, using the beryllium-copper brazing technique of Warner. This provided a rigid reinforcing rim to which a suitable mounting member is hard-soldered. The .020-inch thickness proved adequate to withstand atmospheric pressure over the 1-inch diameter area while subjected to outgassing temperatures.

A variety of vacuum tube construction techniques are employed in attaching the window assembly to the porcelain donut body. The porcelain, compounded to have expansion characteristics similar to those of kovar sealing glass, permitted direct fusing of the porcelain body and a kovar window mount. The various other elements, including injector, grounding stem, and peeler, were sealed into the body using techniques that are standard practice for betatron X-ray donuts. The sealing lathe with alignment fixture to insure accurate positioning of the elements mounted on the donut is shown in Figure 10. As the last step in the assembly, the window assembly is flame welded into the kovar mount previously sealed to the donut. An exploded view of the window assembly and the elements involved is shown as a part of Figure 7.

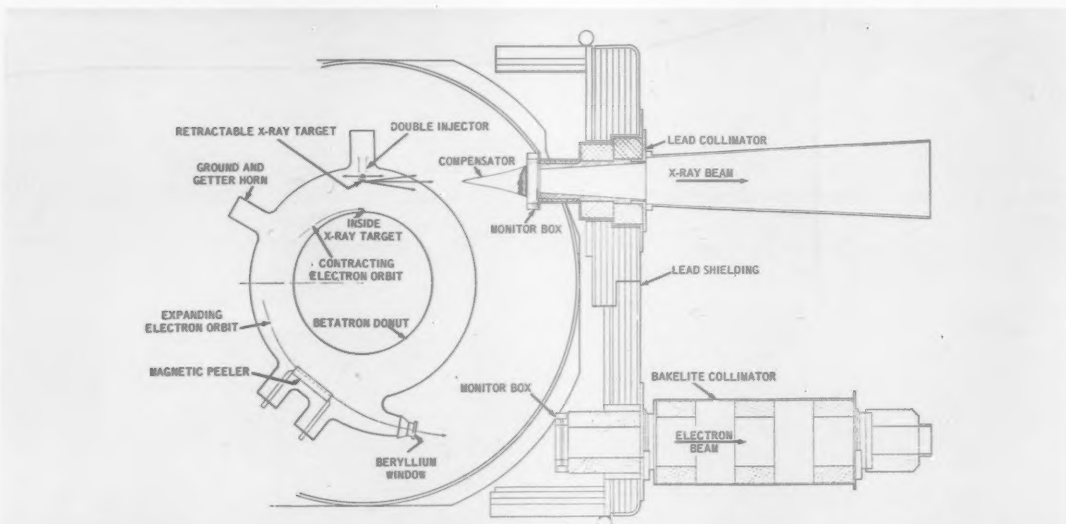
Essentially the same processes used in pumping the standard X-ray donut, including prolonged baking at elevated temperature to rid the structure of occluded gases, are used in evacuating the electron beam tube. After pumping, the tube is ready for operational tests and final positioning of the peeler for maximum output. This is done with the tube installed in a betatron. During the adjustment operation, beam intensity is monitored at all times with a transmission type parallel-plate ionization chamber.

**PRECISION LATHE** and alignment fixtures assure accurate sealing-in of betatron tube components. **(FIGURE 10)**

Collimation of the electron beam to any desired area is accomplished by a special collimator, arranged as indicated in Figure 11. Made of low density material, such as lucite or bakelite, it absorbs electrons without generation of intense X-rays. For collimation of X-ray beams, a heavy material like lead or tungsten is generally used.

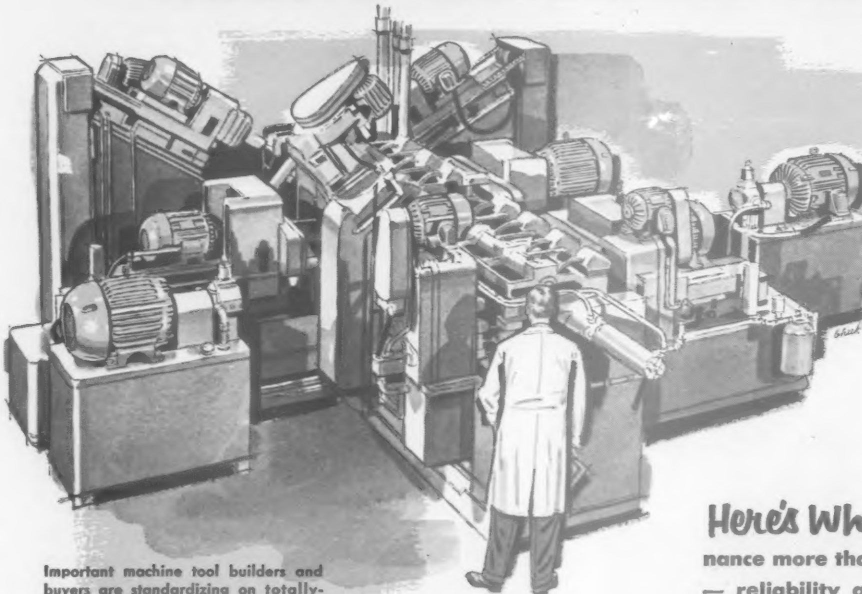
A number of these new electron tubes are now in process, and it is anticipated that their availability as a "stock item" will become an accomplished fact during this year of 1954.

With this new tube, even broader areas of application are opened for the 22-mv betatron—a commercially available machine that has become a standardized tool for research, medical therapy and industrial radiography.



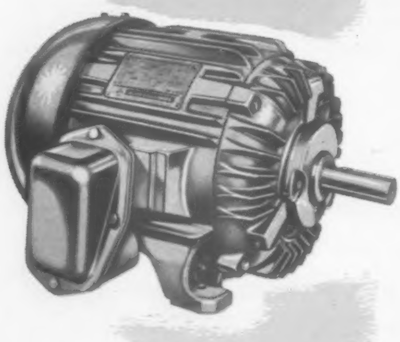

**COLLIMATING** and shielding apparatus for electron beam and X-ray emission betatron are combined in this drawing. **(FIG. 11)**

# Preference for *Totally enclosed* Motors Soars Since 1948!



**Here's Why: reduced maintenance more than pays for added cost — reliability and service continuity are extra benefits.**

Important machine tool builders and buyers are standardizing on totally-enclosed motors. This Transfer-matic built to JIC standards by The Cross Company for a large automotive supplier uses 22 Allis-Chalmers totally-enclosed motors.



MORE and more industries of all kinds are standardizing on totally-enclosed motors. The ratio of these to open motors is steadily rising. Economy-minded managements find it pays to use these motors almost everywhere even though the initial price is higher than for open motors.

**It's a Better Investment**—Totally-enclosed motors are protected against most of the causes of expensive maintenance and premature failure. Experience proves that the low maintenance and dependability which result from this protection make the use of totally-enclosed motors a sound economic practice.

**Allis-Chalmers Motors Pace the Trend** — Eight years ago, Allis-Chalmers introduced its fin-type, totally-enclosed motor. Since that time, the fin-type design has become the most popular totally-enclosed motor on the market.

For all the facts, contact your A-C office or distributor. Or, write Allis-Chalmers, Milwaukee 1, Wisconsin.

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